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HUMAN BIOLOGY

a record of research

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a record of research

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HUMAN BIOLOGY
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FEBRUARY, 1956

VOL. 28 No. 1

ESSAY ON A FUNDAMENTAL LAW OF LIFE
THE TIME–FACTOR (RELATIVITY) IN BIOLOGICAL PHENOMENA

BY E. R. N. GRIGG
Kankakee, Illinois

A modern discourse on the essence of life (*i. e.*, what it is), particularly when reinforced with teleologic phraseology (*i. e.*, why it is as it is), can be more elaborate than a similar composition of antique vintage. It can also be more technical, by virtue of advances in biochemistry, but it cannot disguise our lack of knowledge in the matter. This unrewarding subject will be avoided in the following text, and the principle hereinafter considered pertains to the rules which shape the process of life (*i. e.*, how it evolves).

PROLEGOMENON

An ancient problem is the identification of life. The solution seems rather obvious in most instances yet the various signs proposed, be it the single Epicurean 'life is motion' or the plural Aristotelian 'food intake, growth, and withering,' reveal shortcomings in some aspect of

life, *e. g.*, the latency stage of seeds. Even quite recently established criteria of vitality fail when applied to the borderline case of crystalline virus proteins.

One way to recognize a living organism could be the evaluation of its response to external influences, a phenomenon with both intrinsic and extrinsic circumstances. This implies an eclectic approach, for in the past the widely accepted dogma of a vital principle required a predominantly intrinsic orientation. The importance of ecologic factors, acknowledged at least since Hippocrates, has received proper emphasis only after mechanistic interpretations began to crowd the extrinsic horizon.

The first mention of *irritabilitas* of living tissues (*viz.*, imbued with vital spirits) can be found in Glisson (1677). Haller's famous experimental series on the contractility of muscles and sensibility of nerves, the theoretic elucubrations of the Brunonians, and the changing philosophical trend bridge the gap to Spencer's generalization that life is the adjustment of internal to external relations. Claude Bernard's *milieu intérieur* and Cannon's *homeostasis* are among the better known contributions to this idea of delicate equilibrium, maintained despite (or perhaps because of) constant disturbances.

FORMULATION

Since adaptation is but one of several possible responses, the range ought to be extended to make the principle all-inclusive: *life has* (or could even be defined tautologically as) *the tendency to eliminate the influence of environmental and internal agencies.* This is visually demonstrated during the microscopic examination of the reactions of *Daphnia magna* and other transparent animals to physical and chemical stimuli, produced as micromovies by Viehoever ('40). Adaptation to the environment and struggle for existence (perhaps with extermination of some external 'agencies'), as described by Darwin, cover many aspects of this fundamental law of life which, in its larger meaning, applies equally well to the economic axiom of supply and demand, to drug addiction, and to man's strife for freedom. Whether successful or not, the elimination tendency persists to the last, even during starvation, trauma, or disease.

The act of elimination, or circumstances incident to it, may actually constitute another influence, causing one or more additional (secondary) elimination responses, included in, or superimposed upon, the initial

reaction. Moreover, two or more external influences may appear within short interval (*cf.* 'interference of excitation' in Verworn, '12, and 'conflicting stimuli' in Rashevsky, '51). The frequent occurrence in nature of such multiple events explains the intricacies and apparent contradictions of life phenomena.

According to the 'law of continuity' of Leibniz, natural occurrences proceed gradually; thus the elimination of either internal or environmental stress follows a smooth, logarithmic pathway. The influence predominates at first, until a critical point (climax) has been reached.

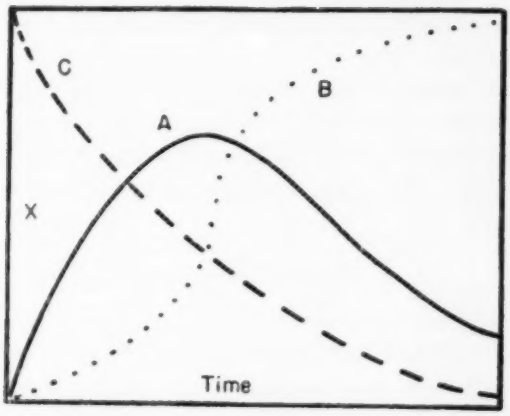

FIG. 1. LIFE'S BASIC TENDENCY IS THE ELIMINATION OF INTERNAL AND ENVIRONMENTAL INFLUENCES. Its graphic expression resembles an *aperiodically damped oscillatory motion* (A), of which a simple formula is $x = \alpha te^{-\beta t}$. The integrated values of A are plotted in B, their reciprocals in C. Examples of observed curves are: A.—Elimination rate (or blood level) of ingested drugs; female fecundity by age groups. B.—Number of resistant bacterial strains after antibiotic therapy; relation between visual acuity and illumination. C.—Activity of an enzyme subjected to x-radiation; tissue retention of ingested substances.

Thereafter, the always longer second phase consists of a gradual return to the base line. A classical example is the response to excitation of striated muscle. This curve (fig. 1, A), known in mechanics as the *aperiodically damped oscillatory motion*, represents the speed of a pendulum, returning to its original position after a single swing, because of the extreme (theoretical) viscosity of the surrounding medium. Its simplest mathematical expression is

$$x = \alpha te^{-\beta t}.$$

A fast reached, high climax must be followed by a relatively earlier decline (fig. 4, i). After a less abrupt ascent, middle-of-the-road values will be maintained for a longer time (fig. 4, ii). Rapidly growing tissue cultures die long before slower developing ones. A similar relationship is noted between the effort rate required for sprint (i) and for marathon (ii), or between the torrentuous sentimental outburst of teenagers and the dignified affective stream of mature individuals. A double alternation of this type has also been shown to exist between urban and extraurban increase rates of the population in Japan (Eto, '41). In many cities tuberculosis mortality exhibited early spiking (i), but it also fell faster, and in many places its figures are now below those (ii) of the surrounding rural areas (L'Eltore, '47).

Integration of above mathematical function gives a sigmoid, growth, logistic, cumulative, summation, or saturation tracing (fig. 1, B). Plotting the reciprocals of the integrated values results in a landing airplane curve (fig. 1, C), often encountered in physics, *e. g.*, expressing radioactive decay.

EXEMPLIFICATION

Patterns analogous to those in fig. 1, and their inverted (mirror) images (fig. 2) abound whenever graphic methods are applied to biometrics (McCarrison and Madhava, '32), especially in physiology, pharmacology, and demography. Quoted for illustration are tissue recovery rates after x-radiation (Kingery, '20), the increase in height of an evergreen tree (Szolnoki, '30), the incidence of decompression sickness as a function of exposure time or temperature (Nims, '51), the assimilation speed of albumin by the liver, determined by tracing radio-sulphur tagged methionine in mice (Khesin, '54), and the tabulation by age groups of intellectual achievements of top grade individuals from various countries (Lehman, '54).

Being man made, economic changes disclose similar developmental cycles. The seasonal fluctuations of certain prices, of the labor market, and of foreign trade volume resemble damped motion curves (fig. 1, A), while saturation tracings (fig. 1, B) describe secular trends in commodity prices, in coal and iron productions, and trade volumes with specified areas (Wagemann, '28). Extrapolative procedures can be adapted, both to short range market problems, and to the long range depression wave forecast, but the frequent overlapping of secondary response cycles causes a regrettable loss in accuracy.

Calculus has also been employed to predict the outcome of biological events, such as speed of wound cicatrization (Lecomte du Noüy, '19), future world population figures (Pearl and Reed, '20), and the length of survival of patients suffering from chronic incurable diseases (Tivey, '54). Paired curves F (fig. 2) and B (fig. 1) may describe two aspects of one phenomenon, for instance, increase in height (F) and weight (B) of newborns, blood dissociation curves of carbon dioxide (F) and oxygen (B), and distensibility of veins (F) and arteries (B).

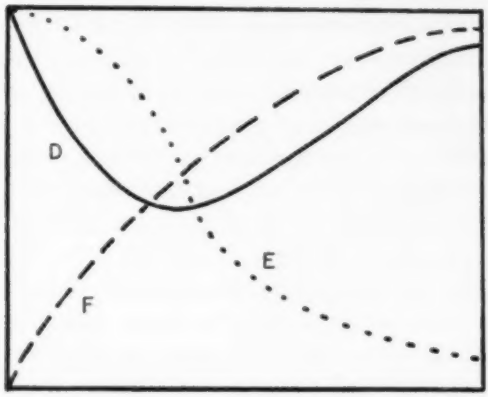

FIG. 2. INVERTED (MIRROR) IMAGES OF THE CURVES IN FIG. 1. Examples of observed tracings: D.—Death rate from accidental poisoning by age groups; respiratory quotient of excess metabolism caused by exercise. E.—Histamine effect on blood pressure in hypertensives; survival of protozoa exposed to high energy atomic particles. F.—Frequency response of sympathetic effectors; isometric muscle contraction.

These six curves (figs. 1 and 2) are calculated paraphrases of damped motion. By inference, the exponential patterns which describe biological occurrences represent transcriptions of the underlying elimination of external or internal influences. Rising air temperature will affect skin temperature, heat loss, and vaporization, but the elimination effect is achieved, as the rectal temperature remains fairly stable (DuBois, '39), and almost identical curves have been obtained in hibernating animals (Chao and Yeh, '50). In practice the identification of the original influence is not always possible, partly for the distortion of observed tracings by the inaccuracy of our measurements, and mainly because of obscuring secondary elimination responses. Moreover, beyond experimental confines, influences of constant strength may not be the rule.

THE ECOLOGICAL IMPETUS

However pernicious, the environmental stress may exert a stimulating effect, in the same way in which a war awakens often unexpected potentialities in a nation. The biologic strength of a community is higher at the end of an epidemic episode of an infectious illness, at which time the natural resistance of its population reaches a peak, after passive selection of the deceased and active immunization of the survivors. This remains statistically correct, even if in the case of scarlet fever some of those who survived may have acquired irreparable kidney disease. In certain chronic infections (syphilis, tuberculosis) major damage is done by the body's response to antigenic influences. Under the circumstances, virulence of a microörganism for a given host is proportional to the extent of reaction. A lessened response is a sign of resistance, while absence of response means immunity. The antigenic influence has been eliminated when the only reaction elicited by the former pathogen is that befitting a saprophyte, a presumption seemingly confirmed by the increasing proportion of tuberculin-negative reactors even among children heavily exposed to bacilliferous parents.

The tracings of either morbidity or mortality during an epidemic wave resemble curve A (fig. 1). For infections with protracted course, such as tuberculosis, secular figures (Gottstein, '48) may be required to demonstrate the actual pattern.

MORS JANUA VITAE

The ultimate in environmental stress is increased mortality of individuals up to and including the reproductive age. This challenge to survival is a prerequisite for the relative immortality of any species and, in a wider sense, for the perpetuation of life itself. The causality may seem heterodox by accepted standards, but only because many of the leading biologists have discarded the Heraclitic concepts, and have sided with Plato for most of the last two millenia. Statistical results do not necessarily apply to the individual, nor are they invalidated by small series. This is emphasized in the commonplace that what is good for the tribe could be evil for one of its members, and vice-versa. Conventional mechanics appear adequate at slow speeds, yet, in accordance with the thesis of Einstein ('13), relativistic adjustments become necessary as soon as momentum has been gathered. Obviously, static biology

applies well to individual cases, or even to linear segments of a given exponential elimination response. Conversely, a dynamic approach is required for the understanding of a long term cyclic phenomenon in a community or species.[1]

War losses are sharp natality boosters, spreading this effect often to neutral territories, a fact reported in Switzerland (Jenny, '42). Psychological mechanisms may be involved, perhaps over endocrine channels. The existence of internal secretion responses to environmental stress has been proved by the pioneering research of Hans Selye. It should be more difficult to uncover the mechanism by which in wartime the usual surplus of male births is also increased, as if intended to prevent the prevalence of females in the general population.

The record breaking civilian and military casualties of World War II have been compensated with compound interest in a few years of armistice, as revealed by mid-century censuses. These include most of the nations with major losses, such as Germany and Great Britain. In some countries (Finland, Italy, The Netherlands, U. S. A.) the total population number never decreased throughout the war years. In the post-war period, overpopulation caused concern not only in Japan (Okasaki, '52), it fostered neo-Malthusianistic efforts all over the world.

The numeric increase of animal populations in their natural habitat follows the usual growth curve (fig. 1, B). The amount of food available, or space limitations cannot completely explain the final leveling off, as similar trends are observed in laboratory bred generations of *Drosophila melanogaster,* and in bacterial and tissue cultures. Perhaps a valid comparison can be made with the growth of trees (Szolnoki, '30), or with the weight increase in mammals, which shows analogous variations, even under pathologic circumstances.

Nonetheless, the levelling off may be postponed under certain conditions. At the height of the saturation tracing (maturity?), a numeric (biologic) balance, however transitory, is established between added (born) and deducted (dead) unities. Any survival challenging disturbance, such as breaking off a piece of tissue culture, will elicit increased mitotic

[1] Among the many attempts to introduce relativistic symbols in biologic metaphysics is the reproduction of a *cuadridimensional* 'wheel of life' (slightly resembling the Brahmanic version of the wheel) by Jakob ('48), included with the statement that life is the fourth degree of the natural maturation of cosmic energy. A transformation of energy is also implied in the formula of Rulfo ('51), based on Rashevsky's interpretation of an application of the Hamiltonian principle by Lotka.

activity (rejuvenescence?), which often overcompensates and reëstablishes saturation at a higher level than before. In the late 1930's, the population of France had reached maturity at about 40 millions and was on the verge of decline. The natality boom caused by the war losses of 1941-45 has reversed the situation: in 1954, at over 43 millions, saturation was still way ahead.

Far from limiting overpopulation, war is today a major factor in producing it. In the Middle Ages, mercenary forces constituted the bulk of every army. In those days low living standards, high infantile mortality, epidemics, floods, and famines were backing natality. The introduction of national armies in modern times has been followed by a sharper increase in world population. Should war be banished from the earth, a saturation point in its population could probably be reached in a not too distant future. The desirability of such a levelling off is a matter which, just like ethics, changes with time, place, and politics, and is therefore beyond the scope of this paper.

Theoretically, the indirect fertilizing value of deceased individuals varies with their age at death. High at birth, it falls off exponentially, and reaches insignificant levels shortly after the average end of the reproductive period. Since the initial peak is actually at conception, interrupted pregnancies should promote the natality increase. For practical purposes, it suffices to distinguish between infantile and adult mortality. The former causes an immediate increase in natality rates, while in the latter a *lag period* will be interposed, to replenish the ranks of the reproductive age group. Hunting regulations, aimed to preserve wild life, follow identical reasonings.

Fulminating disasters of geologic or cosmic origin could wipe out the life on an island, on a continent, perhaps on the entire planet. Short of eradication, catastrophic death rates, such as those obtained during certain insecticidal and germicidal procedures, result only in prolongation of the lag period, with ultimate restoration. Strains resistant to D. D. T., or to antibiotics, have emerged as a proof of life's consistent tendency to eliminate any disturbing influence. In man, on a smaller scale, a similar instance was the survival (and revival ?) of the American Indians. So far, no war has come anywhere close to causing catastrophic death rates of world-wide magnitude, but improved thermonuclear devices might lead to such an accomplishment in the future. It is safe to assume that even then the human race will emerge from the cinders, although the lag period could be lengthy.

Civilization has reduced infantile death rates in many countries, leading to a decrease in natality, quite evident in the interval between wars, even if the interpretations vary from one author to another. The gruesome ritual sacrifice of children and virgins by primitive peoples, intended to foster fertility, may have an empirical rather than a metaphysical rationale. This observation should not be misinterpreted as condoning or advocating death by war or in any other way. The notions of good and bad are alien to nature, they had to be created by man. Newborn bear cubs are sometimes devoured by their father, and this occurrence is not uncommon among other animals. Whether civilized or savage, kin or no kin, a big fish will prey upon little fishes. And yet, the naturalists who first reported these obvious facts have been accused of the intention to recommend similar procedures for human beings. Man is part of the natural world and, even if the evidence is unpalatable or may mean a painful readjustment of his beliefs, he must go on searching for knowledge, for without his curiosity he would be nothing (Adrian, '54).

THE CHANGING TIDE OF DEMOGRAPHIC DEVELOPMENT

During the life cycle of a nation, its population figures follow the ascending pathway of a sigmoid curve, continued with the latter's inverted image (fig. 3). The growth begins with slowly rising numbers: this is the above mentioned *lag*, found also in bacterial, tissue, and protozoa cultures. The change to the second period, a steep slope of exponential multiplication, often coincides with, or perhaps causes, historical changes such as the American Revolution. (The biological background of military and political events is seldom recognized, even in retrospect.) At maturity, with a stationary population, the tracing enters a horizontal, saturation phase. Yet, there is no true stationary phenomenon in life. The threshold is due to prolongation of the individual life span, which maintains an apparent stability of the total population number, despite a dwindling natality. Death is bound to come, and when the accumulated surplus of old age groups becomes part of the mortality statistics, there is a sharp falling off, the stage of decay.

The last portion of the curve (broken segment of the population tracing in fig. 3) straggles toward a virtual parallel with the base line, as seen in the vitality decay of *Uroleptus mobilis* in isolation cultures

(Calkins, '33). In the case of a nation, a slow end is seldom, if ever, seen. As in the fall of the Roman Empire, long before the theoretical finish, demographically younger population groups take over, biologically or otherwise. Each of the newborn nations continues its own pathway on a similar cycle, but the start is not at the base line; it is at the point to which the ethnological mixture has set it back on the biological clock (as usual, most important for common mortals is the relative, not the absolute time).

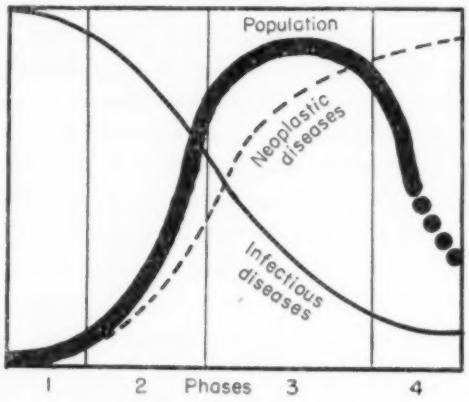

FIG. 3. THEORETICAL POPULATION CURVE DURING THE LIFE CYCLE OF A NATION. The four phases can be duplicated in the laboratory with bacterial, protozoa, or tissue cultures: lag, exponential multiplication, saturation, and decay. The end is often abrupt, as the aging population is incorporated by its neighbors. The resulting newborn nation(s) will continue a similar development from a starting point (rejuvenation or reversal of the biologic clock) determined by the degree of racial intermingling. With advancing biologic time, there is a decrease of infectious diseases (as well as of natality, and of general and infantile mortality), and an increase of neoplasms (and also of other degenerative diseases, of the individual size, and of longevity). The maturation point of population growth may be reached earlier if the death rate declines ahead of time (civilization), or it may be delayed by added mortality (war ?) with consequent increase in natality and infectious diseases, and decrease of neoplasms.

A composite curve, resembling the population tracing in fig. 3, is often encountered in nature, *e. g.*, the pressor response of the heart rate. The excitation state during coitus evolves in a similar fashion (Van de Velde, '26), the acme (orgasm) corresponding to the saturation phase. In the male, regardless of duration of the lag period, the summation time preceding the acme is shorter (steep ascent), consequently the

defervescence stage ends faster than in the female (Rohleder, '11). Analogous differences in speed and reaction time exist between the adrenergic and the cholinergic responses of the neuro-vegetative system. This serves to emphasize that the pendular aspects of the various dualistic systems in nature, such as the concept of Yin and Yang in ancient Chinese medical lore, reveal an asymmetry which can be explained by the inherent features of the respective reaction curves. Fewer females are born, but they live longer (*cf.* the concept of *Geschlechtsströme* in

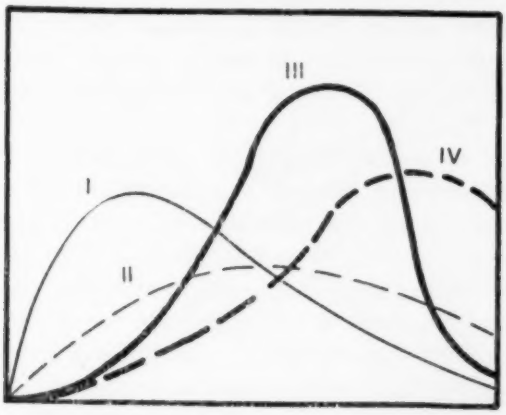

FIG. 4. MASCULINE AND FEMININE TRACINGS. The numeric values, replacing α (height) and β (slope) in the basic formula, determine the shape of the curve. The two extremes, in the simple form (i, ii), or transposed into composite tracings (iii, iv), represent contrasting entities, *e. g.*, acute (i, iii) and chronic (ii, iv) diseases, animals (i, iii) and vegetables (ii, iv), even abstract notions, such as functional (i, iii) and organic (ii, iv). It seems that also symbolically life is built on the dualistic system (pendular but asymmetric) of the male (i, iii) and female (ii, iv) principles.

Rauber, '00), and prevail numerically in aging populations. The surplus of males in younger communities is preserved, despite war losses (in part by migration), as shown already by Graunt (1676). These and other dissimilar findings in the two sexes, somatic and psychologic, in health and disease, can be traced back to the masculine and feminine types of response to disturbing influences (fig. 4). They are substantialized in the different numerical values given to α (magnitude of response) and β (steepness of slope) in the male and female curves calculated from the basic formula.

CONSEQUENCES OF THE DEMOGRAPHIC EVOLUTION

Among the numerically important causes of natural death are infectious and neoplastic diseases. Their respective frequency varies during the life cycle of a nation (fig. 3). The observed decline of infectious pathogenicity is not entirely the result of public health measures. In the past, pandemies such as leprosy, and repeated epidemic waves of typhus, cholera, and plague have receded spontaneously. This decline is difficult to evaluate when considering recent figures, because of the intensive sanitary activity, which in civilized nations has succeeded to reduce, or practically to eradicate, certain diseases, such as the once so dreaded Yellow Fever. Nevertheless, some logical deductions can still be made.

In the case of diphtheria, not too many authors believe that the serum was the cause of the last half century's drop in death rates; furthermore, vaccination with anatoxine did not prevent the outbreak of recent epidemics (Morton, '41; Merkel, '51). The opinion has been expressed that incomplete vaccination accounts for the outbreaks: if this can be accepted, what is left to account for the overall decline of diphtheric morbidity and mortality? In Finland treatment with sulphonamides and penicillin has had little or no effect on the mortality rate of pneumonia, which had started to fall much earlier (Peltola, '54). Likewise, tuberculosis figures began to come down many decades, in some places even centuries, before the introduction of isolation measures (today still incomplete). In fact, in all three instances the decrease slowed down as the curve approached the base line. This is inherent to its exponential function and must not be misinterpreted as the contra-selective result of hygienic and medical techniques.

Nicolle ('30) has pointed out that epidemic outbreaks can be explained by a sudden increase in microbial virulence, due to spontaneous mutations; conversely, the virulence cannot decrease in the same way, because it is unlikely for identical mutations to appear simultaneously in astronomic numbers of bacteria; the lowering of infectious morbidity and mortality can be explained by the natural selection of those with either innate or acquired resistance. One should again realize that values may be reversed at the individual level: at times, antidiphtheric serum effects startling recoveries in desperate cases; the lifesaving usefulness of penicillin needs no reminder; and newborns must be separated from mother who have active pulmonary tuberculosis (fig. 5).

The increasing incidence of neoplastic diseases (fig. 3) is only in part an expression of changing age distribution with preponderance of the older groups. Other degenerative conditions (baldness, tooth decay, refraction defects) and certain nosologic groups (metabolic, endocrine, allergic) are also on the increase, which suggests the possibility of biologic deterioration of the germinative cells. Old infusoria cultures reveal how repeated mitoses in a cell series result in monster formation from incomplete division, and in other degenerative changes, both in nucleus and protoplasma.

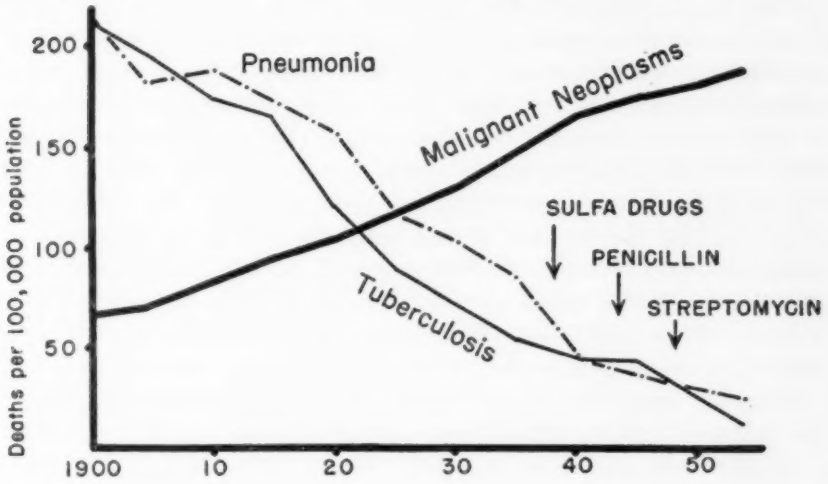

FIG. 5. INFECTIONS AND NEOPLASTIC MORTALITY IN NEW YORK STATE. The tracings have been drawn from five-year interval data supplied courteously by the Biostatistical Office of the Health Department of the State of New York. The advent of three 'wonder-drugs' is marked with arrows. For individual cases, these three drugs have delayed the fatal issue (lifesaving is a poetical misnomer with a prosaically provisional connotation: we must all die some day) more often than all the other antibiotics combined. Still, when viewed through the widened perspective of large figures, a comparison is permissible with La Fontaine's fable of the horsefly which helped to pull the carriage by waving its wings while hanging on to the horse's neck.

Infectious diseases prevail among younger age groups, and as such are a threat to survival, which is of help in maintaining high natality figures, but it also elicits a response tending to eliminate these ailments. Neoplastic diseases affect mostly older people, and therefore do not challenge the survival of a population; on the contrary, their increase

coincides with a prolonged life span. Actually, the population's fertility should benefit (indirectly) from fatal malignancies appearing before the end of the reproductive period, but this influence is small, because of the relative rarity of tumors in younger individuals with consequently minimal total loss in reproductive man-years. On the other hand, when in certain infectious diseases, during the last stages of their epidemiologic cycle, the resistance of the younger generations causes a shift toward older groups, this results in a commensurate decrease in the effect of these particular ailments on natality.

Diagnostic incongruities in the past, and the prolonged life span of the present were assumed to account for, but cannot fully explain, the mounting neoplastic morbidity. In Austria, a physician-coroner's inquest is compulsory for every death certificate, adding considerably to the accuracy of mortality statistics: as their death rate from malignant blastomata has remained fairly stable for the last 25 years, a concomitantly sharp rise in the total neoplastic mortality was interpreted as a proof that cancer does increase independently of age distribution (Puntigam, '47). This is also borne out by age-adjusted cancer death rates for the United States: 80 per 100,000 in 1900, 97 in 1910, 105 in 1920, 113 in 1930, and 120 in 1940 (Moriyama and Gover, '48). The figures are still rising; they were close to 125 in 1950.

Actually, within a nation, various geographical subdivisions, cities, even minority groups folllow their own life cycles, similar to that of the entire nation, but not necessarily coincidental. There are proportionally more infectious and less neoplastic diseases in the rural population than among city dwellers. A recent study by the Bureau of Ethnic Research of the University of Arizona revealed that Arizona Indians are comparatively (1) more liable to die of infectious diseases, and (2) less susceptible to 'constitutional' ailments (neoplastic, allergic, metabolic, endocrine, circulatory), while (3) their elevated natality causes a steady 1–2% annual increase in their total number, despite (or shall we say, because) of a high general, and especially infantile, mortality.

A sizable source of etiological speculation was the undeniable fact that in mental hospitals the incidence of tuberculosis appears higher, the life span shorter, and the proportion of neoplasms lower than in the communities of origin of the respective institutional populations (Grigg, '55). Statistical comparison shows that the overall rates in mental patients trail the national average by 10-20 years, as if the

psychotic condition could reverse the biologic clock, a supposition enhanced by the alleged high potential fertility of mental patients. According to Lamont ('48), in South African mental institutions the 'Cape Coloureds' (a heterogenous ethnic group, mainly of Hottentot and Bantu origin, with both Asiatic and European inflexions) die more often of tuberculosis than patients of pure European descent; even when tuberculosis is excluded, the white chronic schizophrenic tends to live longer. Racial differences in the degree of neoplastic malignancy were also revealed by the calculations of Greenwood ('26), based on Janet Lane-Claypon's statistical material assembled in the general population.

Whatever the interpretations offered, it is undoubtedly true that *there are no basic, standard, average, or otherwise stable morbidity or mortality rates of either infectious or degenerative* (including neoplastic) *diseases*. The continuous changes observed are the consequence of advancing biologic age, while rate differences between two or more racial or geographic groups are in fact phase differences.

Life's ultimate goal is complete elimination of all disturbing influences, particularly of the environmental stress, yet if and when achieved, it leads to the death of the respective biologic group. Disappearance of the gigantic Cretaceous dinosaurs, the most powerful and elaborate creatures of their time, was probably due to failing reproduction, but minuscule lizards are still available to impersonate their bygone kinship in the magnifying perspective of movie cameras. When a group advances in biologic age, its individuals increase in size, but decrease in fertility, *viz.*, the difference between Scandinavians and Mediterraneans. Similar discrepancies may be noted between urban and rural areas and, moreover, since purity of race or clan can substitute for its age, between the inbred patriciate and the intermixing plebe. Large mortality rates of 'traumatic' origin can maintain a short stature and high natality over long periods of time (Jews, Chinese). Maybe civilization, by raising the life standard and lowering the death rate, accelerates the biological aging process. Suits of armor in museums are too small for the average man of today. Berths on sleeping cars have been lengthened by half a foot in the past eighty years. Skeletons of the extinct Cro-Magnon race, the most civilized in prehistoric times, are often from oversized individuals. It might be of interest to determine proportionally the procreative contribution of the tall, 'career-girl' type of woman.

EPICRISIS

The primary purpose of the preceding considerations was to establish accurate causal relationships between basic biological events. The universal validity of the enunciated principle and the multiplicity of life are reflected in the diversity of instances quoted. As stated, an essential tendency of living matter is the drive to eliminate the influence of any environmental or internal agencies. This elimination occurs in two unequal phases, of which the second is the longer one. Paradoxically as it may seem, ultimate analysis reveals that the aforementioned influences, especially those which constitute a threat to survival, are necessary for the perpetuation of life. The superimposition, in practice, of interfering, secondary response cycles serves as a convenient safety device for the benefit of those who cherish the doctrine of "indeterminism." [2]

Also intended was a reëvaluation of the relative importance of extrinsic versus intrinsic factors. Certainly, the environmental influences are of extraneous origin, but as soon as the response has been started, the endogenous component prevails. Proper blending of microbial virulence with the host's response is a prerequisite for the development of any infectious ailment. By analogy, the appearance of a malignancy requires a carcinogenic agent and a favorable constitutional background. Identification of the exogenous component, be it some highly hypothetical virus or any of the actual carcinogens in a given case (bronchogenic carcinoma), could not explain *per se* the observed increase in neoplastic diseases, which is an intrinsic feature of the advancing cycle of population growth. The progressive constitutional degeneration is substantiated in the gradual lowering of the threshold of cancer-producing dose for all the carcinogens, including the particular agency (smoking ?). This would also explain the increased neoplastic susceptibility of certain varieties among the highly inbred stock of laboratory animals.

Back in the sixteenth century, syphilis appeared sometimes as an acute fever (de Baillou 1660), often with fatal outcome in a matter of weeks; it is today almost invariably chronic, and kills indirectly, if

[2] The 'physiological determinism' of Claude Bernard had similar difficulties, *cf.* Boussinesq (1877). More recently, widespread acceptance of the quantum theory was facilitated by the fact that Planck's hypothesis can be adjusted to any degree of unpredictability, even if in the opinion of Barbour ('55) it has failed to provide a final answer in the attack on mechanistic and reductionistic determinism.

at all. The debased leprosy, and the more recent withering of the tuberculous pandemy are also arguments in favor of Sydenham's allegoric representation of infectious diseases as falling empires. The tumors follow the opposite path, and study of their natural history at different times and places should reveal a progressive increase in the degree of malignancy (with shift toward younger age groups?) as well as a proportional reduction of the five-year survival rate in untreated cases.

Lecomte du Noüy ('36) discussed 'biological time' as related to the aging process of the individual (wounds heal faster in children), and mentioned briefly a *temps de l'espèce*. The idea of pathologic changes related to advancing time was applied by Grote ('48) to the phasic phenomena, of which there are many examples in medicine. Actually, the concept must be extended until today's prevailing postulate of the fixity of diseases shall appear as absurd as the fixity of species. Comparison at face value of treatment statistics of either infectious or neoplastic diseases is a fallacy, unless due consideration is given to the biologic age of the respective demographic groups. This is one of the main reasons why results of animal experimentation do not have to apply in man. Further generalization will emphasize the continuous change in relation to time as an essential feature of life phenomena. Even the converging, diverging, and interfering cycles which constitute the biocosmos could be imagined in the form of a gigantic maze, expanding spherically as it floats with poise along a damped pathway toward infinity.

ADDENDUM

Thomas Huxley expressed the warning that it is the customary fate of new truths to start out as heresies and to end up as superstitions. In the beginning, the theoretical basis of this paper may be opposed, mainly by those who employ wishful thinking in their search for finality in nature. At some later date, the fundamental law of life will probably be evaluated from the viewpoint of obtaining "desirable" changes, a task both delicate and unrewarding. Considering our microcosmic limitations, the ultimate in wisdom calls perhaps for acceptance of the macrocosm as it is, trying to change less, and to understand more of the *Dark Philosopher*'s harmonious, universal reason, the *logos*. And maybe the fire which he regarded as the world's basic element is actually the symbol of life, ever changing in the constantly flowing nature of things, for undoubtedly *πάντα ῥεῖ*.

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THE ABO BLOOD GROUPS AND THE SEX RATIO

BY BERNICE H. COHEN * AND BENTLEY GLASS

The Johns Hopkins University, Baltimore

FROM the Biblical peoples who sought by divine aid to beget sons rather than daughters and from the primitive societies which have tried to control their populations by female infanticide, to those 20th century biologists who have been investigating the etiology of the proportions of males to females, interest in the sex ratio has been universal. In the course of time, comprehension has proceeded from the spiritual to the practical realm and back to the no less mysterious laws of probability—that there is slightly better than a 50/50 chance that the Y–bearing spermatozoon will outdistance the X–bearing one.

It is well established that less than fifty girls are born for every fifty boys (Ciocco, '38; Bernstein, '51, '52, '53; Jalavisto, '52a, b; Lienhart, '52; *et al.*). Actual estimates of the excess of males among live births vary for different populations and conditions: from low estimates of 103 and 104:100 for Salvador and Japan respectively to a high of 113-140:100 in Greece and Korea, 1921-1929 inclusive (Russell, '36). In the U. S. Birth Registration Area ± 105-106:100 was reported for 1917-1934 (Ciocco, '38); and "in 19164 cases collected from Finnish and Swedish published family history records," a fairly normal male birth rate, 107:100, for the nobility and "a considerably higher sex ratio" 122:100, for middle class families (Jalavisto, '52b). Moreover, the primary sex ratio at conception [males/(males + females) times 100] is not necessarily the same as the sex ratio at birth (Ciocco, '38; Tietze, '48; Bernstein, '51, '54; Dahlberg, '51). More stillbirths and more spontaneous abortions are thought to occur among males than among females, particularly at certain stages of gestation (McKeown and Lowe, '51; Jalavisto, '52a), although the study of Tietze ('48) calls this conclusion in question. He obtained a sex ratio of 107.9:100 in

* Public Health Service Research Fellow of the National Heart Institute.

a study of 5787 embryos and fetuses of the 3rd to 7th months of pregnancy.

Within recent years there have been many reports in regard to the influence, or lack of influence, of numerous factors on the sex ratio:

Birth order	(Russell, '36; Ciocco, '38; Lawrence, '41; Martin, '43; MacMahon and Pugh, '53)
Family size	(Russell, '36; Lawrence, '41; Thomas, '51; Jalavisto, '52b)
Sex of first-born	(Lancaster, '50)
Maternal age	(Martin, '43; Lowe and McKeown, '50; Jalavisto, '52a, b; Takahashi, '52, 54a, b; Bernstein, '53; Novitski, '53; Myers, '54)
Paternal age	(Jalavisto, '56b; Bernstein, '53; Novitski, '53)
Relative ages of father and mother	(Ciocco, '38; Lawrence, '41; Bernstein, '53)
Ancestral longevity	(Lawrence, '41; Jalavisto, '52b)
Action of genes through the endocrine system	(Bernstein, '51)
Physique and temperament	(Heath, '54)
Physiological and biochemical factors (mice)	(Weir, '53)
Artificial insemination	(Jalavisto, '52b)
Frequency of intercourse	(Jalavisto, '52b)
Time of conception during menstrual cycle	(Lawrence, '41; Jalavisto, '52b)
Seasonal and monthly variation	(Russell, '36; Ciocco, '38; Takahashi, '52)
Geographical and climatic conditions	(Ciocco, '38)
Illegitimacy	(Ciocco, '38)
Race and color	(Ciocco, '38)
Parental occupation	(Bernstein, '51, '54)
Social status and socio-economic conditions	(Russell, '36; Ciocco, '38; Lawrence, '41; Martin, '43; Bernstein, '53, '54)
Urban-rural and other differences	(Russell, '36; Ciocco, '38)
War and post-war periods	(Russell, '36; Myers, '49; MacMahon and Pugh, '53, '54)

One of the most provocative reports of any was published in 1951 by Sanghvi. It indicated a certain relation between the ABO blood-group constitution of mothers and offspring and the sex ratio at birth but left the possible cause of such blood-group/sex-ratio correlation

obscure. Maternal isoimmunization is here ruled out because the reported differences occurred in combinations where mother and infant were of identical blood groups, such as A/A; and no data have ever suggested any linkage between the autosomal ABO blood-group factors and the X–Y chromosomes (see Sanghvi, '51; Johnstone, '54). Yet the marked similarity between Sanghvi's two independent samples of widely different populations, taken respectively in New York and Bombay, is very striking. These results, together with the suggestive findings of Waterhouse and Hogben ('47) concerning the differential fertility of reciprocal matings, particularly A × O compared with O × A, and of Allan ('52) concerning fertility differences in mothers and fathers of different blood groups, have led us to undertake a further investigation of those problems on some Baltimore population samples. Meanwhile, Johnstone ('54) has published a study, similar to that of Sanghvi, upon a West London population. In the present paper, which will be concerned primarily with the relation of the sex ratio to parental ABO blood groups, the Baltimore data will be presented in detail, will then be compared with the data reported by Sanghvi and by Johnstone, and will finally be combined with the other series to form a pooled sample wherein statistical variability is lessened. Further studies on the differential fertility rates of various mating types, and a comparison of the Baltimore data with the findings of Waterhouse and Hogben and of Allan, will be presented elsewhere.

SOURCE OF MATERIAL

The original data were taken from the records of the Baltimore Rh Typing Laboratory for the years 1947 through 1953, inclusive. Two separate series were tabulated. The first (Balto. Rh) consists of Rh-negative non-sensitized women married to Rh-positive men. Every history in the "non-sensitized" files was utilized if it specified the ABO blood group of the mother and the blood group and sex of one or more children, provided that there was no contradiction or inexplicable discrepancy in the record (such as AB mother and O offspring, or discrepancy between replicate blood typings). The father's blood group was tabulated whenever it was available. Sensitized mothers were excluded because maternal isoimmunization tends to cause a higher rate of stillbirths and neonatal deaths. In view of the possibility, already mentioned, that there may be a sex differential in pregnancy wastage,

and because this might apply to losses due to Rh incompatibility as well as to other causes, any influence of the ABO blood groups on the sex ratio of the offspring might be distorted or masked by Rh hemolytic disease.

The second series (Balto. Pat.) consists of cases of mothers and offspring typed in connection with disputed paternity suits at law. These were of mixed Rh types, and thus serve as a control series for checking the randomness as respects the ABO groups of the larger Rh-negative non-sensitized series. In this series no male parents were included.

METHODS

In both Baltimore series (Rh and Pat.) there were families in which the blood group of the mother and the sex and blood groups of more than one offspring were available. These families were consequently tabulated in two different ways: (1) as *multiple determinations per family* (table 3), each offspring being used in a separate parent-offspring combination; and (2) as a *single determination per family* (table 3), in which case only the oldest child of known sex and blood group (not necessarily the oldest child in the family) was used to represent the family. Selection of the oldest child was made because of the greater reliability for blood typing of venous blood samples than of cord blood from newborn infants; and also in order to eliminate possible errors due to postponed development of the blood type, as reported to occur in the case of the group A antigen.

The two Baltimore samples (Rh and Pat.) are tabulated separately, and so are the data from single and multiple determinations per family within each series. Inasmuch as the comparison of these series revealed no significant statistical differences between the Rh and the Paternity series, either according to single ($\chi_{14}^2 = 13.81$; $.50 > P > .30$) or multiple ($\chi_{14}^2 = 17.28$; $.30 > P > .20$) determinations per family, the Rh and Paternity series have been combined in a Pooled Single Series and a Pooled Multiple Series.

In addition to the large pooled samples (Balto. Pooled Mult., B–S–J), each series is presented independently in order to demonstrate that the deviations are not a function of the method of sampling. From inspection of the separate samples, it is apparent that the results are not influenced by an ABO–Rh interaction, as has been suggested for isoimmunization (Levine, '43; Fisher, '44; Race and Sanger, '50; Mollison,

Mourant, and Race, '52; Heistö, '55). In the Balto. Pat. series and the Johnstone series, both of which are composed of mixed Rh types, similar deviations appear as in the Balto. Rh series composed of Rh-negative non-sensitized mothers and Rh-positive fathers exclusively. It is likewise apparent that the results are not influenced by any selective action against infants of certain ABO blood groups in the early years of life as opposed to a prenatal effect, an hypothesis that might be suggested by the autopsy studies of Struthers ('51). For, while the Baltimore samples included offspring irrespective of age (including about 50% of cord bloods), three other samples included newborn infants only. Both Sanghvi series—Bombay and New York—used cord bloods, and Johnstone in his West London series utilized "tube techniques on all mothers delivered in the maternity department of West Middlesex Hospital . . . [throughout the year 1950]." Not only do all the samples show the same major trends independently but cell by cell they are not significantly different from one another (see the χ^2 values for the differences between series making up pooled samples, pp 23, 28, 30, 31).

For the sake of simplicity in tabulation and reference, the sex ratio is indicated in the form of the percentage of males among all tabulated offspring, rather than as the number of males per 100 females. In all the following tables, wherever matings are designated, the blood group of the female parent stands first, and the male follows. Although this violates what has become a convention in referring to human matings, it accords with the practice of geneticists who work with other species of plants or animals, and there seems to be no good reason for those who are discussing human genetics to deviate from common practice and thereby introduce inconvenience if not confusion.

For the statistical analysis of proportions, the chi square test was selected as being both the most reliable and the most practical (Cochran, '52; Fisher and Yates, '53). We have utilized a somewhat different method of analysis from that of Sanghvi or Johnstone. Sanghvi compared A/A mother-offspring blood group combinations with O/O, and also with B/B, as being combinations "large enough for further observation." It appears better to base the analysis upon the entire sample, and then, by partitioning χ^2, to determine what combinations contribute most significantly to the variance. We will also compare (1) the sex ratios in the total offspring of parents of each of the four blood groups; (2) the sex ratios among total O, A, B, and AB offspring, respectively, disregarding the parental blood group; and (3) the sex ratios in the

complete series of parent-offspring combinations of matched blood groups, *viz.*, O/O, A/A, B/B, and AB/AB. The third of these comparisons would be that in which the least extraneous interaction, such as that producible by isoimmunization, would be expected to occur.

SUBJECTS

When multiple ascertainment was used, there were 3577 mother-offspring combinations in the Rh series and 961 in the Paternity series. The two Baltimore series combined thus virtually equal in sample size the three combined series of Sanghvi (Bombay; New York) and Johnstone (London), previously reported. In the Baltimore Rh series 3037 individual families were represented; in the Paternity series, 900 mothers. From the Rh series alone came the 2827 father-offspring combinations (table 4) and the 2295 mating combinations (table 5).

Both Rh and Paternity samples comprised mixed racial groups. Only White and Negro classifications were available from the records; the few Mongoloids present were probably included with the Whites. The Rh series was 86.8% White, whereas the Paternity series contained only 25.0% of Whites. When pooled, the two series were approximately 74% White. Because the data of the Baltimore Rh Laboratory are used primarily for obstetrical purposes, more detailed information is collected for mothers than for fathers. Both age and race were indicated for 2941 mothers of the Rh series; race but no age was given for 767 mothers of the Paternity series.

The blood type distribution by race (table 1) shows, as would be expected, a smaller proportion of A and a larger proportion of B among Negro mothers than among White mothers. The distribution appears to be a representative sample of both White and Negro populations in eastern United States, at least in urban areas of the Middle Atlantic States. The frequencies for the Negro population agree very well with those reported by Glass and Li ('53) for a Baltimore Paternity series, although the present data given in table 1 are based on the Rh series alone. The present frequencies for the Baltimore Whites likewise agree closely with those used by Glass and Li, which were derived from New York City (Tiber) and North Carolina (Snyder) (see references in Glass and Li, '52).

From table 2 it may be observed that a similar proportion of each blood group occurs in each age group. The percentage of each blood group

within an age group falls within the confidence limits for the total individuals in that age group, with the exception of two cells containing very small numbers. There is a relatively small proportion of AB mothers in the 20-24 year-old age group, but this is not significantly different

TABLE 1

Blood Group Distribution of White and Negro Mothers of Baltimore Rh Series

	O			A			B			AB			TOTAL
	BALTO.		GLASS AND LI	BALTO.		GLASS AND LI	BALTO.		GLASS AND LI	BALTO.		GLASS AND LI	BALTO.
	No.	%	%	No.	%	%	No.	%	%	No.	%	%	
White	1109	43.5	45.2	1048	41.1	39.5	296	11.7	11.2	99	3.9	4.2	2552
Negro	185	47.6	47.6	108	27.8	28.3	83	21.3	20.0	13	3.3	4.1	389
Total	1294			1156			379			112			2941

The frequencies of ABO blood types used by Glass and Li ('53) and quoted above were derived from New York City and North Carolina Whites and Baltimore Paternity Series Negroes, and hence are different samples from the Baltimore Rh group of this study.

TABLE 2

Age Distribution of Mothers (Rh Series) According to Blood Group

	O		A		B		AB		TOTAL	
AGE	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
<20	123	9.5	114	10.8	37	9.8	12	10.7	286	9.7 ± 1.8
20–24	379	29.3	314	27.2	114	30.1	26	23.6	833	28.3 ± 1.6
25–29	431	33.4	369	31.9	118	31.1	36	32.1	954	32.4 ± 1.5
30–34	258	20.0	246	21.3	69	18.2	23	20.5	596	20.3 ± 1.7
35 +	103	8.0	113	9.8	41	10.8	15	13.4	272	9.2 ± 1.8
Total	1294		1156		379		112		2941	

from the largest proportion of 20-24 year-old mothers, the B mothers [t value = 0.699; not significant]. The other exception is to be found in the relatively large proportion of AB mothers over 35 years of age. Again, this is not significantly different from the group of mothers, of group O, yielding the smallest proportion past 35 years of age. Hence any possible bias due to the influence of maternal age upon the sex ratio is excluded.

RESULTS

The data and the statistical analyses given in tables 3 through 6 are largely self-explanatory. Only a few pertinent facts need be brought out.

TABLE 3a

Sex Ratio and Mother-Offspring Blood Group Combinations

OFFSPRING		MOTHERS O NO.	O %	A NO.	A %	B NO.	B %	AB NO.	AB %	TOTAL NO.	TOTAL %
O	Balto. Pooled Single	**1179**	**50.8**	456	50.7	175	50.3			1810	50.7
	Balto. Rh Multiple	**1027**	**50.6**	432	52.1	148	51.4			1607	51.1
	Balto. Pat. Multiple	**326**	**53.4**	94	46.8	49	49.0			469	51.6
	Balto. Pooled Multiple	**1353**	**51.3**	526	51.1	197	50.8			2076	51.2
	Sanghvi Bombay	**231**	**60.5**	88	52.3	97	54.6			446	57.6
	Sanghvi N. Y.	**272**	**56.3**	99	45.5	42	50.0			413	53.3
	Johnstone	**756**	**50.9**	271	53.5	70	58.6			1097	52.1
	Pooled Balto.–Sanghvi–John.	**2642**	**52.6**	984	51.3	406	53.0			4033	52.3
A	Balto. Pooled Single	423	51.5	**857**	**47.7**	68	52.9	75	49.3	1423	49.2
	Balto. Rh Multiple	407	51.4	**828**	**48.3**	57	57.9	64	51.6	1356	49.8
	Balto Pat. Multiple	82	54.9	**176**	**42.6**	20	40.0	21	47.6	299	46.2
	Balto. Pooled Multiple	489	51.9	**1004**	**47.3**	77	53.3	85	50.6	1655	49.1
	Sanghvi Bombay	105	47.6	**217**	**49.8**	35	57.1	32	50.0	389	49.9
	Sanghvi N. Y.	106	51.9	**186**	**45.7**	12	50.0	12	75.0	316	49.1
	Johnstone	275	54.2	**691**	**49.9**	20	55.0	35	60.0	1021	51.5
	Pooled B–S–J	975	52.1	**2098**	**48.3**	144	54.2	164	54.3	3381	49.9
B	Balto. Pooled Single	196	54.1	74	39.2	**232**	**56.9**	60	61.7	562	54.1
	Balto. Rh Multiple	169	53.3	69	44.9	**178**	**59.6**	60	53.3	476	54.4
	Balto. Pat. Multiple	52	50.0	13	15.4	**87**	**52.9**	14	78.6	166	51.2
	Balto. Pooled Multiple	221	52.5	82	40.2	**265**	**57.4**	74	58.1	642	53.6
	Sanghvi Bombay	78	57.7	47	48.9	**215**	**57.7**	43	58.1	383	56.7
	Sanghvi N. Y.	44	47.7	11	63.6	**44**	**65.9**	11	63.6	110	58.2
	Johnstone	72	54.2	47	61.7	**81**	**54.3**	30	43.3	230	54.4
	Pooled B–S–J	415	53.3	187	49.2	**605**	**57.7**	158	55.7	1365	54.9
AB	Balto. Pooled Single			67	58.2	53	45.3	**22**	**59.1**	142	53.5
	Balto. Rh Multiple			59	57.6	59	44.1	**20**	**55.0**	138	51.5
	Balto. Pat. Multiple			17	52.9	7	71.4	**3**	**66.7**	27	59.3
	Balto Pooled Multiple			76	56.6	66	47.0	**23**	**56.5**	165	52.7
	Sanghvi Bombay			41	46.3	46	54.3	**25**	**56.0**	112	51.8
	Sanghvi N. Y.			**11**	**81.8**	8	50.0	**6**	**66.7**	25	68.0
	Johnstone			34	47.1	36	50.0	**11**	**45.5**	81	48.1
	Pooled B–S–J			162	53.7	156	50.0	**65**	**55.4**	383	52.5
TOTAL	Balto. Pooled Single	1798	51.3	1454	48.7	528	53.0	157	55.4	3937	50.8
	Balto. Rh Multiple	1603	51.1	1388	49.7	442	54.5	144	52.8	3577	51.1
	Balto. Pat. Multiple	460	53.3	300	43.3	163	50.9	38	60.5	961	50.1
	Balto. Pooled Multiple	2063	51.6	1688	48.6	605	53.6	182	54.4	4538	50.8
	Sanghvi Bombay	444	57.0	393	49.9	393	56.5	100	55.0	1330	54.6
	Sanghvi N. Y.	422	54.3	307	47.6	106	56.6	29	69.0	864	52.8
	Johnstone	1103	51.9	1043	51.3	207	55.1	76	51.3	2429	51.9
	Pooled B–S–J	4032	52.6	3431	49.5	1311	54.9	388	55.2	9162	51.8

Mother-Offspring Combinations. In table 3 only the pooled totals of the Rh and Paternity series involving single ascertainment per family have been entered, inasmuch as the two series did not exhibit any significant differences. Although there are also no significant differences between them, the separate Rh and Paternity series involving multiple ascertainment per family are given, in order to permit the comparison of effects on the sex ratio in the two series with different proportions of Whites and Negroes, and with selected vs. unselected Rh types. Inasmuch as the Pooled Single and Pooled Multiple series are not dissimilar ($\chi_{14}^2 = 0.67$; $P > .99$), the latter has consistently been used for the comparisons with the series compiled by Sanghvi and Johnstone. Furthermore, the statistical analysis having shown that that Baltimore series does not differ significantly from the pooled New York and Bombay series of Sanghvi or the London series of Johnstone, these have all been combined in one Pooled B–S–J Sample ($\chi_{28}^2 = 25.44$; $.70 > P > .50$).

In both Baltimore samples, Rh and Paternity, by either multiple or single ascertainment per family, and in agreement with Sanghvi's data, the total offspring of A mothers and the A offspring of all mothers exhibit a relatively low sex ratio, *i. e.*, the proportion of males in each case falls below 50%. Although in Johnstone's series the corresponding values exceed 50%, they are nevertheless below the total sex ratio for his series (51.9) and for the pooled Baltimore-Sanghvi-Johnstone data (51.8). In the pooled data there is a highly significant reduction in the sex ratio for the total offspring of A mothers (P almost 0.001) in comparison to B, AB, and O mothers; and there is a significantly low sex ratio among the A offspring of all mothers, in comparison to the B, AB, and O offspring of all mothers ($P < 0.01$). [An inconsistency may be seen in the fact that, whereas the mother-offspring tabulation yielded a significantly low sex ratio for the total A offspring, the father-offspring tabulation (table 4), based on 1085 of the 1356 A offspring in the Rh multiple ascertainment series, did not.] Of the independent samples, however, only the pooled Sanghvi series reaches levels of statistical significance for these differences.

As might be expected from the low sex ratio of all offspring of A mothers and the low sex ratio of the A offspring of all mothers, the A/A mother-offspring combinations in particular show a consistently low sex ratio in comparison with the other matched mother-offspring combinations (B/B, AB/AB, and O/O); and this is true not only of the Baltimore and Sanghvi series but also of Johnstone's series (49.9). The

TABLE 3b

Statistical Analysis of Sex Ratio in Mother-Offspring Combinations

I. Pooled Baltimore-Sanghvi-Johnstone Sample
Total and Partitioned χ^2 Values

CELL (Mother-offspring)	χ^2	D.F.	PROBABILITY	SIGNIFICANCE
O/O	.6310	1	$.50>p>.30$	
O/A	.0277	1	$.90>p>.80$	
O/B	.3359	1	$.70>p>.50$	
A/O	.0106	1	$.95>p>.90$	
A/A	10.6249	1	$.01>p>.001$	***
A/B	.5141	1	$.50>p>.30$	
A/AB	.2225	1	$.70>p>.50$	
B/O	.2000	1	$.70>p>.50$	
B/A	.3226	1	$.70>p>.50$	
B/B	8.2968	1	$.01>p>.001$	***
B/AB	2157	1	$.70>p>.50$	
AB/A	.3907	1	$.70>p>.50$	
AB/B	.9430	1	$.50>p>.30$	
AB/AB	.3266	1	$.70>p>.50$	
TOTAL =	23.0621	$14-1=13$	$0.05>p>0.02$	*

II. Categorical χ^2 Determinations on Pooled B–S–J and Independent Samples

SAMPLE	χ_c^2	PROBABILITY	SIGNIFICANCE
1. Offspring of O, A, B, and AB Mothers			
Pooled B–S–J	15.554	$0.01>p>0.001$	***
Balto. Pooled Single	4.92	$0.20>p>0.10$	
Balto. Pooled Multiple	6.61	$0.10>p>0.05$	
Sanghvi (Pooled B–N. Y.)	9.336	$0.05>p>0.02$	*
Johnstone	1.003	$0.90>p>0.80$	
2. O, A, B, and AB Offspring (irrespective of maternal blood type)			
Pooled B–S–J	10.621	$0.02>p>0.01$	**
Balto. Pooled Single	4.317	$0.20>p>0.10$	
Balto. Pooled Multiple	4.225	$0.30>p>0.20$	
Sanghvi (Pooled B–N. Y.)	8.002	$0.05>p>0.02$	*
Johnstone	1.065	$0.70>p>0.50$	
3. Mother-offspring Matching Combinations: O/O, A/A, B/B and AB/AB			
Pooled B–S–J	19.455	$p<0.001$	****
Balto. Pooled Single	7.105	$0.10>p>0.05$	
Balto. Pooled Multiple	10.068	$0.02>p>0.01$	**
Sanghvi (Pooled B–N. Y.)	11.270	$0.02>p>0.01$	**
Johnstone	0.950	$0.90>p>0.80$	
4. O/O versus A/A Combinations (χ_c^2)			
Pooled B–S–J	8.897	$0.01>p>0.001$	***
Balto. Pooled Single	1.886	$0.20>p>0.10$	
Balto. Pooled Multiple	3.671	$0.10>p>0.05$	
Sanghvi Bombay	5.57	$p<0.02$	**[1]
Sanghvi N. Y.	4.93	$p<0.05$	*[1]
Sanghvi Pooled	10.07	$0.01>p>0.001$	***
Johnstone	0.178	$0.70>p>0.50$	

[1] From Sanghvi's calculations.

* $= 0.05>p>0.02$ *** $= 0.01>p>0.001$
** $= 0.02>p>0.01$ **** $= p<0.001$.

pooled B–S–J totals show a highly significant difference in the sex ratio of the matched mother-offspring combinations (P less than 0.001); and even the Baltimore Pooled Multiple and Sanghvi Pooled series taken independently attain the 0.02 level of significance.

Johnstone's report of a high sex ratio in the total offspring of B mothers is not only confirmed in Sanghvi's two series, but also in the Baltimore Rh series, although it did not show up in the Baltimore Paternity series. For the pooled Baltimore series, and also for the pooled B–S–J series, it considerably exceeded the over-all sex ratio, by 2.8% and 3.1%, respectively. Thus the high sex ratio among the offspring of B mothers, like the low sex ratio among offspring of A mothers, contributed to the high significance (P less than 0.01) of the difference in the sex ratio which is found to exist among the offspring of the 4 types of mothers in the pooled B–S–J sample.

The AB mothers also exhibit a high sex ratio (55.2) among their total offspring, but the numbers of these, even in the pooled B–S–J sample, are not large enough to indicate whether the difference is real or not.

The B offspring of all classes of mothers exhibit a high sex ratio (54.9). This is primarily attributable to the B offspring of B mothers, and exists in spite of the low sex ratio of the B offspring of A mothers in the pooled B–S–J sample. Thus a study of the data summarized in table 3 indicates that the low sex ratio of all offspring of A mothers and of the A offspring of all mothers is chiefly attributable to the same cause, namely, the low sex ratio of the A offspring of A mothers. Similarly, the high sex ratio of all offspring of B mothers and of the B offspring of all mothers is chiefly attributable to one class, the B offspring of B mothers. The B offspring of A mothers show a low sex ratio, but the numbers are too small to make the difference from the general sex ratio significant; and the A offspring of B mothers show a high sex ratio, but again the numbers are too small to warrant any conclusion.

Father-Offspring Combinations. Since the Baltimore Rh multiple series of father-offspring combinations does not differ significantly from Johnstone's father-offspring series ($\chi_{14}^2 = 7.867$; $.90 > P > .80$), they have been pooled. Table 4 shows that the low sex ratio for all offspring of B fathers (49.0), reported by Johnstone, is confirmed in the Baltimore Rh Multiple Ascertainment series (46.7); but even when pooled, the

difference was significant only at the 5% level. No other significant differences appeared in the interrelations of father's and offspring's blood groups and sex.

TABLE 4a

Sex Ratio and Father-Offspring Blood Group Combinations Pooled Baltimore Rh Multiple and Johnstone Samples

		Fathers									
		O		A		B		AB		Total	
Offspring		no.	%	no.	%	no.	%	no.	%	no.	%
O	Baltimore	**805**	**53.5**	348	50.0	114	50.9			1267	52.3
	Johnstone	**630**	**52.9**	267	52.4	73	49.3			970	52.5
	Pooled B–J	**1435**	**53.2**	615	51.1	187	50.3			2237	52.4
A	Baltimore	306	50.7	**695**	**52.2**	42	33.3	42	47.6	1085	50.9
	Johnstone	250	51.6	**606**	**51.7**	17	47.1	27	48.1	900	51.4
	Pooled B–J	556	51.1	**1301**	**52.0**	59	37.3	69	47.8	1985	51.1
B	Baltimore	90	56.7	59	59.3	**162**	**46.3**	54	59.3	365	52.9
	Johnstone	52	46.2	21	42.9	**92**	**48.9**	31	74.2	196	51.5
	Pooled B–J	142	52.8	80	55.0	**254**	**47.2**	85	64.7	561	52.4
AB	Baltimore			54	48.1	46	50.0	**10**	**60.0**	110	50.0
	Johnstone			37	45.9	28	50.0	**10**	**60.0**	75	49.3
	Pooled B–J			91	47.3	74	50.0	**20**	**60.0**	185	49.7
Total	Baltimore	1201	53.0	1156	51.7	364	46.7	106	54.7	2827	51.8
	Johnstone	932	52.1	931	51.5	210	49.0	68	61.8	2141	51.8
	Pooled B–J	2133	52.6	2087	51.6	574	47.6	174	57.5	4968	51.8

Mating-Offspring Interactions. Table 5 gives the available data supplied from Johnstone's and the Baltimore Rh Multiple Ascertainment series. Sanghvi did not report on the sex ratio in offspring from different types of mating. Again, because of the lack of any statistically significant difference between them ($\chi_{16}^2 = 9.36$; $.90 > P > .80$), the Baltimore and Johnstone series have been pooled.

As would be expected from the low sex ratio observed independently in all offspring of A mothers and in all offspring of B fathers, there is a marked deficiency of males in the progeny of the mating A ♀ × B ♂. There is also a low sex ratio in the offspring of A ♀ × A ♂. Neither of these differences, nor the distribution as a whole, reaches a level of statistical significance. However, the very high sex ratio from O ♀ × AB ♂ is at the .01 level of significance.

Johnstone emphasized only the low sex ratio in the progeny of B fathers and the high sex ratio in that of B mothers (table 6A). Allan ('54), observing this, suggested also that "such opposing parental tendencies may also be found to a lesser extent in O and A fathers and mothers." This aspect was unconfirmed by the Baltimore data. In the

TABLE 4b

Statistical Analysis of Pooled Baltimore–Johnstone Sample

[N. B. Categorical χ^2 tests of Baltimore and Johnstone samples respectively yielded no statistically significant deviations and therefore only the analysis of the Pooled B–J Sample are included here.]

I. Total and Partitioned χ^2 Values—Pooled B–J Sample

CELL	χ^2	D.F.	PROBABILITY	SIGNIFICANCE
O/O	1.2074	1	$.30>p>.20$	
O/A	0.1152	1	$.80>p>.70$	
O/B	0.0649	1	$.80>p>.70$	
A/O	0.1322	1	$.80>p>.70$	
A/A	0.0148	1	$.95>p>.90$	
A/B	0.3405	1	$.70>p>.50$	
A/AB	0.7394	1	$.50>p>.30$	
B/O	0.1671	1	$.70>p>.50$	
B/A	5.0239	1	$.05>p>.02$	*
B/B	2.0861	1	$.20>p>.10$	
B/AB	0.0920	1	$.80>p>.70$	
AB/A	0.4237	1	$.70>p>.50$	
AB/B	5.7032	1	$.02>p>.01$	**
AB/AB	0.4006	1	$.70>p>.50$	
TOTAL	16.5090	$14-1=13$	$.30>p>.20$	

II. Categorical χ^2 Determinations — Pooled B–J Sample

a. Offspring of O, A, B, and AB fathers: $\chi_3^2 = 7.0340$, $0.10>p>0.05$ NSD
b. O, A, B, and AB offspring: $\chi_3^2 = 1.0668$, $0.80>p>0.70$ NSD
c. O/O, A/A, B/B, and AB/AB father/offspring combinations: $\chi_3^2 = 3.6914$, $0.30>p>0.20$ NSD

poled B–J sample, the dissimilar offspring of mothers classified according to blood group (O, A, B, AB respectively) did not show a significantly different sex ratio from those of fathers of the corresponding blood groups. Allan called attention to the reversed order of magnitude of the sex ratios in the offspring of mothers compared with fathers ($B>O>A$ and $A>O>B$ respectively) found in Johnstone's data; the Baltimore sample (table 6) neither shows the same order as Johnstone's nor any other in which the order in the mothers is the converse

of that in the fathers. The actual orders are O > B > A and O > A > B for Baltimore mothers and fathers, respectively. As might be expected, the Pooled B–J sample follows the Baltimore series, which is larger than the Johnstone series. Even the difference between the sex ratio of the

TABLE 5

Sex Ratio and Parental Mating Types Based on ABO Blood Groups Baltimore and Johnstone Samples

Mating	Number of Matings		Offspring				Sex Ratio		
			Male		Female				
Mother-Father	Balto. No.	Johnstone No.	Balto. No.	Johnstone No.	Balto. No.	Johnstone No.	Balto. %	Johnstone %	Pooled %
O × O	420	446	454	412	456	387	49.9	51.6	50.67
O × A	402	401	446	353	408	340	52.2	50.9	51.65
A × O	399	386	410	351	389	350	51.3	50.1	50.73
O × B	135	95	156	81	144	86	52.0	48.5	50.74
B × O	118	71	132	74	110	59	54.5	55.6	54.93
O × AB	48	26	43	39	32	15	57.3	72.2	63.57
AB × O	38	24	42	27	35	25	54.5	51.9	53.49
A × A	357	402	369	370	376	371	49.5	49.9	49.73
A × B	115	84	106	73	126	84	45.7	46.5	46.01
B × A	139	75	151	73	146	63	50.8	53.7	51.73
A × AB	41	27	56	20	45	23	55.4	46.5	52.78
AB × A	33	29	29	28	34	35	46.0	44.4	45.24
B × B	23	16	21	15	26	10	44.7	60.0	50.00
B × AB	8	8	8	8	7	3	53.3	72.7	61.54
AB × B	14	8	17	6	10	7	63.0	46.2	57.50
AB × AB	5	2	4	1	4	2	50.0	33.3	45.45
Total	2295	2100	2444	1931	2348	1860	51.0	50.9	50.97

$\chi_{15}^2 = 19.032$ $.20 > p > .10$ N.S.D.

offspring of B mothers and of B fathers so emphasized by Johnstone and by Allan is not statistically significant in the pooled data ($P > .20$). The evaporation of this difference in the course of extending the size of samples points up the need for greater caution in drawing conclusions from supposed differences that lack statistical significance.

DISCUSSION

Amid all the natural variance, the data compared here yield, when pooled, a pair of highly significant relationships. In the A offspring of A mothers there is a lowered sex ratio—that is, there are actually

TABLE 6

Sex Ratio of Offspring of Parents Classified According to Blood Group
(Excluding Combinations in Which Parent and Offspring are of the Same Blood Group)

A.

	O				A				B				AB				TOTAL			
	MOTHERS		FATHERS		MOTHERS		FATHERS		MOTHERS		FATHERS		MOTHERS		FATHERS		MOTHERS		FATHERS	
OFFSPRING:	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%	NO.	%
Baltimore	710	52.1	396	52.0	684	50.4	461	51.0	340	50.6	202	47.0	159	54.1	96	54.2	1893	51.4	1155	50.9
Johnstone	347	54.2	302	50.7	352	54.0	325	51.1	126	55.6	118	49.2	65	52.3	58	62.1	890	54.2	803	51.4
Pooled B–J	1057	52.8	698	51.4	1036	51.6	786	51.0	466	51.9	320	47.8	224	53.6	154	57.1	2783	52.3	1958	51.1

Sex ratio of offspring of Pooled B–J Mothers of each blood group versus sex ratio of offspring of Pooled B–J Fathers of same blood group $\chi_4^2 = 2.114$ $.80 > p > .70$ N.S.D.

B.

	ORDER OF PARENTAL BLOOD GROUPS		
	MOTHERS		FATHERS
SEX RATIO:	HIGH	MID LOW	HIGH MID LOW
Baltimore	O	B > A	O > A > B
Johnstone	B	O > A	A > O > B
B–J Pooled	O	B > A	O > A > B

fewer males than females; and in the B offspring of B mothers there is a raised sex ratio. When the 5 separate series are examined, these relations appear with high consistency. In both Baltimore series, whether taken by single or by multiple ascertainment, in both of Sanghvi's series, and in Johnstone's series, the sex ratio for the A/A mother-offspring combination is always below 50.0; and in the pooled data, comprising over 2000 recorded births, it is only 48.3. The B/B mother-offspring combination is far less numerous, comprising only 605 births in the pooled data; but its sex ratio (57.7) is the highest of any mother-offspring combination. In only two cases (Balto. Pat. Mult., 52.9; Johnstone, 54.3) does it drop below 55.0; and in both those instances it still considerably exceeds the over-all sex ratios of 50.1 and 51.9 for those series, respectively. Both A/A and B/B combinations exceed the 0.01 probability level.

The pooled B offspring of A mothers also show a low sex ratio (49.2), although the data are not so consistent. However, the number of such births (187) is not large and the statistical variance is consequently high. The pooled A offspring of B mothers conversely show a suggestively high sex ratio (54.2). The number of such offspring (144) is even smaller, and the variance too great to permit any firm conclusion. Nevertheless, there is a suggestion here that the low sex ratio applies to both A and B offspring of the A mothers; and the high sex ratio to both A and B offspring of B mothers.

These are the facts. It remains, if possible, to suggest some sort of biological mechanism that could conceivably bring about these reciprocal shifts in the sex ratio. Recalling that males are produced through the functioning of spermatozoa each carrying a Y–chromosome, and females through the functioning of spermatozoa each carrying an X–chromosome, one may see that what is indicated is clearly some sort of reaction between the maternal genotype, or the genotype of the egg itself, and the relative success of the two types of sperm cell.

The first explanation to spring to mind is naturally that the A offspring of A mothers and the B offspring of B mothers, which exhibit the respectively low and high sex ratios, are homozygous. The data, upon inspection, serve to exclude this possibility. In the first place, homozygotes would also be expected to occur among the A offspring of A fathers and the B offspring of B fathers, but table 4 reveals that the sex ratio in the former class is not low and in the latter class is not high. Moreover, homozygotes are excluded in the classes, B offspring of A mothers

and A offspring of B mothers. Among the matings indicated in table 5, homozygotes for A should occur in the progenies of A × A, A × AB, AB × A, and AB × AB. None of these deviate significantly from the over-all sex ratio, and the A × AB and AB × A matings, which according to this explanation should yield identical results, seem to deviate in opposite direction from the average sex ratio. The inviability or reduced occurrence of homozygous A males could not at all account for the low sex ratio in the mating of A × B, which, however, lacks statistical significance. The hypothesis is accordingly insufficient to explain the deviations which do occur and predicts deviations which do not occur.

Because I^O is a commoner allele in the populations studied than either I^A or I^B, most of the A offspring of A mothers must come from matings of A × O and A × A in which the A individuals are heterozygous. Both of these types of mating are expected to yield some O offspring; and in fact all the O offspring of A mothers must come from heterozygous mothers in which an O-bearing egg is fertilized by an O-bearing sperm. Consequently, the sex ratio of the O offspring of A mothers will tell us whether or not the O-bearing spermatozoa, in fertilizing O-bearing eggs in an A mother, produce a lower frequency of males than expected. Table 3 shows that the sex ratio in this class is 51.3, which is certainly not significantly low (P between .95 and .90). One may reason similarly that the O-bearing spermatozoa produce the expected proportions of males and females when fertilizing O-bearing eggs in a B female, for the sex rat o found (53.0) is not significantly different from 51.8 (P between .70 and .50). In fact, table 3 shows that O-bearing spermatozoa yield a normal sex ratio in O, A, and B females, if fertilizing O-bearing eggs. It may further be deduced from table 5 that the O-bearing spermatozoa produce a normal sex ratio when fertilizing eggs carrying A, for the mating A ♀ × O ♂ yielded a normal sex ratio (50.73) in a total of 1500 offspring. The B ♀ × O ♂ has a higher sex ratio (54.93), but the deviation from the mean sex ratio of 50.97 for the matings in table 5 is not significant (P greater than .10). It would see to follow that the observed significant deviation in the sex ratio are not attributable to the O-bearing spermatozoa at all and must consequently be attributable to A-bearing and B-bearing spermatozoa.

We may next examine the data to see whether both O-carrying and A-carrying eggs produced by the A mothers, the majority of whom are heterozygous, are involved, or only one sort; and similarly whether both

O–carrying and B–carrying eggs from the B mothers are involved, or only one sort. In matings of AO females with A– males, the offspring from O eggs fertilized by A sperms cannot be distinguished from the offspring derived from A eggs fertilized by A or O sperms; likewise for the matings of BO females with B– males. But in the mating of AO females with B– males, and conversely of BO females with A– males, the two types of zygotes are phenotypically distinguishable. The AB offspring, in both cases, arise from the egg that carries the allele corresponding to the mother's phenotypic blood group. The B offspring from A mothers and the A offspring from B mothers arise from the fertilization of the eggs carrying O. Table 3 shows that the sex ratio among the pooled AB offspring of the A mothers is certainly not low (53.7); and among the pooled AB offspring of the B mothers it is certainly not high (50.0). On the other hand, the pooled B offspring of the A mothers (sex ratio 49.2) and probably the pooled A offspring of B mothers (sex ratio 54.2) do deviate in the expected directions. These facts inform us that the phenomenon probably arises from the union of O–bearing eggs, in mothers of phenotypes A and B, with spermatozoa bearing A or B. The extreme deviation is found when the sperm carries the same blood group gene as the mother's phenotype, A in A, or B in B.

A mechanism now suggests itself, although for the present it must remain purely hypothetical. It is well known that many individuals carry a dominant secretor gene, *S*, which brings about the secretion of the A or B antigenic substances into the body fluids, such as saliva, lymph, and tissue fluid. In a heterozygous person the diploid cell is protected against highly specific chemical reactions of an enzymatic or immunological type by the presence of both alleles in the nucleus. Following meiosis, however, there come into existence germ cells of a haploid constitution, and thus in a heterozygous mother, eggs of type O are exposed to the A or B antigens. The O eggs in an A mother might then react in an unusual way with spermatozoa also carrying A. One must postulate that in this case more of the O eggs are fertilized by A–X sperms than by A–Y sperms, or else, if fertilization is normal, that more AO–XY than AO–XX zygotes perish. The opposite happens in the case of B mothers. The mechanism implies that there is some modification of the reaction by the alternative presence of the X or Y chromosome; yet there must be a considerable cross-reaction, for in the A mother the O eggs manifest a similar, though weaker, reaction toward the B–X and B–Y sperms, as toward the A–X and A–Y sperms.

The alternative hypothesis that in segregation the A tends to go with the X and the B with the Y, in AO and BO males, respectively, may be ruled out. If it held true, B fathers should in general produce more sons, and A fathers more daughters; but table 4 shows that this is definitely not the case.

This brings us to a situation that is capable of test. Matings of A × A or B × B that produce some O offspring must be between parents both of whom are heterozygous. The mothers of such families must therefore produce O–bearing eggs. One-third of the A offspring of the A × A mating and one-third of the B offspring of the B × B mating are expected to be derived from O eggs fertilized by A and B sperms, respectively. The former should result in a low sex ratio among the A offspring according to the theory, and the latter in a high sex ratio among the B offspring; whereas the O offspring from each mating should exhibit a normal sex ratio. Similarly, from matings of A females by AB males or matings of B females by AB males, the production of B offspring in the former mating or of A offspring in the latter mating will indicate that the mother is heterozygous (AO or BO) and a producer of O–bearing eggs. In the mating of AO ♀ × AB ♂, one-half the offspring of blood group A would come from the fertilization of an O egg by an A sperm, and all of those of blood group B would be derived from an O egg fertilized by a B sperm. Both these classes should exhibit a low sex ratio, according to the theory. In the mating of BO ♀ × AB ♂, one-half the B offspring and all the A offspring would conversely be expected to show a high sex ratio.

There is no test of these relations in the present data, but it should be pointed out that, although the theory satisfies the deviant ratios in the mother-offspring combinations (tables 3), there are certain discrepancies in the father-offspring combinations (table 4). In the latter, the most significant deviation, that of the high sex ratio (64.7) for B offspring of AB fathers, is not inconsistent with the theory. On the other hand, the low sex ratio (37.3) in the A offspring of B fathers is inconsistent with the theory, since such offspring could arise only from the functioning of an O–bearing sperm fertilizing an A–bearing egg produced by an A or AB female.

A possible consequence of the postulated mechanism would be that AO and BO mothers might not only yield abnormal sex ratios in their offspring, but might also show deviations in fertility rates and expected numbers of A and B offspring, respectively.

It is now quite apparent that future work on this problem will have to supply full information, not only in regard to both parents, but also in regard to the sex ratio in each separate category of offspring. A tabulation of this sort has been started, but it will take a considerable time to secure adequate samples for even the commonest categories.

SUMMARY

1. Two Baltimore samples, one from the files of the non-sensitized Rh-negative women and the other from the Paternity Suit files of the Baltimore Rh Typing Laboratory, have been examined for evidence of any relationship between the ABO blood groups and the sex ratio, in comparison with other data on this relationship previously published by Sanghvi (Bombay and New York series) and by Johnstone (London series).

2. From a study of the mother-offspring combinations, a consistent and, in the pooled data, significantly *low* sex ratio was found among all offspring of mothers of blood group A and among the total offspring belonging to blood group A irrespective of mother's type. Both of these are attributable chiefly to the low frequency of males among the A offspring of A mothers, although there is an indication that the B offspring of A mothers also have a low sex ratio.

3. There is a consistent and, in the pooled data, significantly *high* sex ratio among all offspring of B mothers and among the B offspring of all mothers. Both of these are attributable chiefly to the high frequency of males among the B offspring of B mothers, although there is an indication that the A offspring of B mothers may likewise have a high sex ratio.

4. There is a significantly high sex ratio among the B offspring of AB fathers and a low sex ratio among the A offspring of B fathers, in pooled Baltimore Rh and Johnstone data.

5. In preliminary tabulations of the sex ratio in progenies derived from the various types of matings when both father's and mother's blood group was known (Balto. Rh and Johnstone series), a significantly high sex ratio was obtained in the mating where mother was O and father AB. No explanation is offered of this deviation from expectation.

6. From an analysis of the data, it is concluded that O-bearing spermatozoa are probably not involved in the production of exceptionally

high or low sex ratios; and likewise that A–bearing or B–bearing eggs are not involved. The phenomenon seems to arise when O–bearing eggs in females of types A or B are fertilized by spermatozoa carrying A or B respectively. A biological mechanism for this is suggested and means of testing the hypothesis are described.

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CRANIAL ALLOMETRY IN THE GREAT APES[1]

BY EUGENE GILES

Department of Anthropology, Harvard University

DESPITE much recent study of cranial growth and morphology in the primates, there has been little consideration of the analytical technique of allometry, as propounded by Julian Huxley ('32). While some trepidation should always be entertained when attempting to express complex developmental factors by simple mathematical formulations, the positive results of such tests as those made by Moss ('54), Robb ('35) and Reeve ('40), to name but a few, encouraged this author to undertake an examination of allometric relationships in the cranial development of the great apes.

Allometry has also been suggested as a mean of describing osteological change in an evolutionary series, and successful applications of this method have been published by Hersh ('34) on titanotheres, Romer ('48) on pelycosaurs, etc. Since no satisfactory paleontological primate series now exists, the author has attempted to simulate such a series with neontological data in order to investigate the degree of affinity among the members of the great ape subfamily.

The reservation should be made explicit that allometry is used here as a tool descriptive of gross morphology, and as an indication of similarities in developmental patterns. Within these bounds certain objections to the allometric scheme on theoretical grounds are effectively countered by the empirical successes of many researchers.

Essentially, allometry measures the difference in rates of growth or of other size increases. Measurements may be taken either of two

[1] I wish to express my appreciation for the very helpful advice given me by Professor W. W. Howells and Dr. Edward E. Hunt, Jr., and also to thank Dr. Howells and Dr. C. P. Lyman for making available to me the primate collections of the Peabody Museum and the Museum of Comparative Zoology, Harvard University.

dimensions of the same organism or anatomical unit, or of a whole organism and a part thereof. Two separate parts of the organism can be analyzed, and considerable success has been had in applications to the chemical composition of the body (*e.g.*, Forbes, '52a, '52b). The allometric formula $y = bx^k$ is fitted to the data (usually in the linear form $\log y = \log b + k \log x$). The coefficient k is the ratio between the two rates of growth measured; when $k = 1$ the rates are equal, and could as well be represented as simple proportions.

MATERIAL AND METHODS

At least three possibilities are present in great ape skulls for allometric investigation. The terminology of Huxley, Needham and Lerner ('41) and Simpson ('53), wherein heterauxesis denotes an allometric relationship in an ontogenetic series and allomorphosis the same in an adult series, provides an adequate nomenclature. A sample of 170 chimpanzee, orangutan and gorilla calvaria from the primate collections of the Peabody Museum and the Museum of Comparative Zoology, Harvard University (see table 1) was analyzed for (1) heterauxesis; (2) individual allomorphosis, or allometry between adults of the same population; and (3) genus-form allomorphosis, or allometry between representative adult members of different but related genera. The latter approach has been applied in the same way as paleontologists use lineage allomorphosis, or allometry between members of a phylum in direct line of descent.

TABLE 1

Primate Material

	MALE ADULTS	FEMALE ADULTS	UNSEXED ADULTS	JUVENILES	TOTAL
Pan sp.	40	37	4	36	117
Pan paniscus	2	1	0	0	3
Gorilla g. gorilla	14	10	0	5	29
Gorilla g. berengei	1	0	0	1	2
Pongo sp.	5	7	0	7	19
Total	62	55	4	49	170

The only age-grouping this material needed was a dichotomous one into still-growing juveniles and matured adults. In all species the criterion used was the eruption or non-eruption of the third molar. The

utility of this division-marker is apparent; its reliability is attested to by the work of Schultz ('40a) for the chimpanzee, Schultz ('40b) for the orangutan, and Randall ('42) for the gorilla.

Measurements were taken with standard anthropometric calipers to the nearest millimeter. The numerical data were transformed into five-place logarithms, and the straight line best fitting the variates (the slope of which is the allometric coefficient k) was determined mathematically, using the procedure described by Kermack and Haldane ('50). The reduced major axis so plotted has been found a better approximation of the allometric curve than the usual least-squares regression line, though its application has so far been limited (*e.g.*, Parkinson, '52). It also has the advantage of allowing the test devised by Finney ('38) to be adapted to indicate the significance level of the difference between k and unity. Of course, if there is no significant difference, then no allometric relationship should be implied, and it is reasonable to assume that a proportional constancy is maintained between the two variables during growth. The linearity of the logarithmic data is suggested by the coefficient of correlation r and its significance level. Tests of significance between two k factors involve the use of the formula developed by Simpson and Roe ('39).

The 7 measurements used were taken in the following manner. *Prosthion* and *basion* are defined as usual. *Palate breadth* is the greatest separation of the external alveolar borders wherever found. *Palate length* is measured from prosthion parallel to the long axis of the palate to the posterior edge of the alveolar arch. *Cranial breadth* and *bizygomatic breadth* are respectively the greatest breadth of the cranium (avoiding the supramastoid crest) and of the zygomatic arch. *Biporionic axis-prosthion* is the calculated distance from prosthion perpendicular to the biporionic axis at its midpoint. *Nasion* presents some difficulties. While it is clear in the immature forms, by the adult stage it has been completely obliterated. Also, especially in the gorilla, the nasal bones may reach up into the glabellar region. The approximation used, following Randall ('42), was the midpoint of a horizontal tangent drawn to the arches formed by the suture between the maxillae and the frontal bones.

In table 2 the values found for k for each of 4 pairs of measurements are presented together with the significance levels of r and of k. In all pairs the first-mentioned variable is used as x, the second as y. The calculation of b, though a simple one of substitution, has been

omitted here because it plays no part in the analysis. Huxley ('32) considers *b* to be of no particular biological significance. Of the results of groups showing significant linearity and having an adequate sample size about 78% showed significant allometry based upon the Finney ('38) test.

In addition to the analysis of the 4 sets of measurements described in this paper, the author made allometric calculations for two other vector pairs: *biporionic axis-vertex* vs. *biporionic axis-prosthion* and *biporionic axis-vertex* vs. *glabella-opisthocranion*. In the former significant allometric relationships were practically nonexistent, and the results of the latter comparison were almost as meager. These pairs were therefore omitted from the present discussion. However, it is worth noting the lack of allometric development in these dimensions, though it is possible that allometry in *biporionic axis-vertex* vs. *glabella-opisthocranion* was obscured by superimposed bone growth directly effected by muscular attachments and expansions.

RESULTS

Because of sample size limitations, heterauxesis was substantially investigated only in the chimpanzee. The allometric coefficients quantify some of the vectors in the general growth syndrome of large-jawed primates. The *k* value of 2.774 obtained in comparing *bizygomatic breadth* with *cranial breadth*, for example, gives a numerical value to the higher rate of face-width growth compared with cranial expansion. Such numerical values permit a much more exact description of differences in growth rates among the various dimensions of the skull. The relatively greater downward growth of the chimpanzee face is measured, as is the faster sagittal growth in the palate compared both to the transverse increase in the palate and to the growth in the cranial base.

The data in table 2, describing the rapid postnatal extension of the muzzle in the great apes, provide a very clear-cut example of allometric growth. As mentioned above, the increase in *palate length* has been found positively allometric both with regard to *palate width* and to a measure of part of the cranial base. This situation is likely common to other relatively large-jawed primates (*e.g.*, Huxley, '32, concerning baboons) and is manifested in other mammalian orders (*e.g.*, Robb, '35, Reeve and Murray, '42 for the horse; Reeve, '42 for South American anteaters.

TABLE 2

	PALATE BREADTH VS. PALATE LENGTH			CRANIAL BREADTH VS. BIZYGOMATIC BREADTH			NASION-BASION VS. NASION-PROSTHION			PALATE LENGTH VS. BIPORIONIC AXIS-PROSTHION MINUS PALATE LENGTH		
Chimpanzee	k	P_k	P_r	k	P_k	P_r	k	P_k	P_r	k	P_k	P_r
All groups	1.675	.01	.001	2.075	.01	.001	1.347	.01	.001	.825	.01	.001
All adults	1.184	.05	.001	1.622	.01	.001	1.583	.01	.005	1.266	.05	.001
Male adults	1.377	.05	.005	1.218	*	.04	1.759	**	*	1.077	*	.005
Female adults	.975	*	.005	1.297	*	.01	1.627	**	*	1.378	.05	.03
Juveniles	1.698	.01	.001	2.774	.01	.001	1.285	.05	.001	.761	.05	.001
Gorilla												
All groups	1.552	.01	.01	2.221	.01	.01	1.397	.01	.01	.957	*	.01
All adults	1.878	.01	.01	1.449	.05	.01	1.322	.05	.01	.801	*	.01
Juveniles	1.453	**	.01				1.737	**	.01			
Orangutan												
All groups	1.411	.01	.01	3.872	.01	.01	1.910	.01	.01	1.138	*	.01
All adults	1.421	*	.01	2.593	.01	.01	.890	*	.01	1.256	*	.01
Juveniles	1.356	**	.01	4.686	**	*	2.368	**	.01	.867	**	.01

Note: see text for explanation of column headings; * = found to be not significant; ** = not tested.

The excess of the *bizygomatic* growth rate compared to that of *cranial breadth* is very much greater in the heterauxetic series than in the three series representing adult allomorphosis. Possibly the large k factor in the juvenile series reflects an adolescent growth spurt in the mandibular musculature that has promoted ossification in the zygomatic arch. The striking rate of sutural and exterior appositional growth of the zygomatic arch has been investigated by Scott ('54), and also in a longitudinal study by Gans and Sarnat ('51). At the time the adult stage is reached, the zygomatic development, as measured by adult allomorphosis, is for practical purposes merely proportional to the general size increase. Whether the technique employed here is a reasonably accurate one for measuring the magnitude of such "growth spurts" can only be determined by further applications of allometry to other cases and by investigation of the precise relationship of muscle mass to bone production.

Heterauxesis in the young of the gorilla and orangutan, where it could be examined, indicates the same trends, though the statistical significance of these is not proved. It should be noticed how well the allometric coefficients for the *nasion-basion* vs. *nasion-prosthion* measurements reflect the increasing preponderance of downward face-length growth relative to growth along the cranial base in the progression from chimpanzee (1.285) to gorilla (1.737) to orangutan (2.368), the latter developing large jaws coupled to a rather paedomorphic braincase.

Though individual allomorphosis concerns itself with an adult population, it is apparent that it does not divorce itself from the individual's growth, since the k factor is determined by the total of the stages each individual reached at the time of growth cessation. In order to justify this coefficient we must assume a category-wide relative growth pattern that is not subject to significant individual variation, a pattern whose implementation but not whose nature is influenced by variation in the "environment" in the sense of total nurture, debilitating diseases, etc., or absolute growth potential. Granting these assumptions, it is possible to consider individual allomorphosis as representing the relative growth rate in, so to speak, the adult stage.

Relevant to this approach is material demonstrated by Huxley ('32) in insects, Reeve and Murray ('42) in the horse, and Forbes ('52a, '52b) in human biochemical studies to the effect that there is a deviation in the heterauxetic line of the data so that two lines forming an obtuse angle provide the best fit. Since the cross-sectional approach necessarily

used here with the juveniles was not exhaustive enough to show this directly, an analysis was made between the adult and the juvenile k factors to show whether the relative growth ratio underwent such a change during development. Accordingly, the significance between the ratios of all the adults and the juveniles was tested for the chimpanzees; the results are presented in table 3. Again, small sample size prevented similar application to the gorilla and orangutan.

Since the samples were of adequate size for the chimpanzee, a test was made for the differences between the male and female adults' rates; none was found significant.

Current taxonomic practice does not regard the genus as a strictly "objective" category. Mayr ('42) seems in accord with the taxonomist who defined the genus as "in general neither too large nor too small." His own definition is more subtle, but he agrees on the "honest admission of the subjective nature of this unit," viewing the genus as a group of species, of common phylogenetic origin, separated by a gap from other such groups, but "it is to be postulated for practical reasons that the size of the gap shall be in inverse ratio to the size of the group."

Both Simpson ('45) and Straus ('49) give each of the great apes generic rank within a separate great-ape subfamily. As Pocock ('25) observed, many early writers were sufficiently impressed by the similarity between the gorilla and the chimpanzee to assign them only specific difference; however, later workers have separated them, even while recognizing affinities between the two, *e. g.*, Remane ('21), Schultz ('27), Romer ('45), Young ('52). Contrary to this trend, Mayr ('50) has suggested that the gorilla and chimpanzee are but polytypic species that should be placed in the same genus.

Huxley ('32) has noted that taxonomists often pay more attention to differences in proportion than to differences in size. But if differences in proportion, such as the greater dolichurany of the gorilla compared with the chimpanzee, are merely the result of a general size increase acting upon an allometrically developing system, such differences are no more significant than size variations. At least one author (Hersh, '34) has made this observation explicit, proposing that differences in k distinguish genera. Even if such value is not placed on allometric similarities and differences, their demonstration can still be regarded as strong indication of affinity. Le Gros Clark ('55) has recently pointed out that the validity of statistical comparisons of anatomical measurements is likely to be greatest in determining the relative affinity of forms known beforehand to be closely related.

TABLE 3

	Significance of difference ADULTS VS. JUVENILES	*Critical Ratios of Differences*						*Genus-form Allomorphosis*
		CHIMPANZEE-GORILLA		CHIMPANZEE-ORANGUTAN		GORILLA-ORANGUTAN		
		JUVENILES	ADULTS	JUVENILES	ADULTS	JUVENILES	ADULTS	*k* VALUES
Palate breadth vs. palate length	None	1.31	—	2.47	—	0.99	—	2.008
Cranial breadth vs. bizygomatic breadth	.001	1.92	0.76	2.79	3.20	2.89	2.87	—
Nasion-basion vs. nasion-posthion	None	0.48	—	3.77	—	3.43	—	1.349
Palate length vs. biporionic axis-prosthion minus palate length	.005	1.98	3.03	3.62	0.07	1.69	1.22	.787

Consequently, tests were made of the significance of the difference of the k factors between chimpanzee and gorilla, chimpanzee and orangutan, and gorilla and orangutan. The coefficients used were derived from the combination of the juveniles and adults. Such combination is questionable where linear allomorphosis and heterauxesis of the same population differ. The usual procedure (*e.g.*, Reeve, '40) has been to disregard the possibility of this difference. However, heterauxesis relies upon fewer assumptions as to its causation than individual allomorphosis, and also usually produces a better fit of the allometric line. Hence, in those categories where a significant difference between these two measures has been shown, the significance of the difference between the species as adults as well as combined groups has been reckoned. Table 3 gives the critical ratios found. Significance at the .05, .01 and .001 levels is assured by critical ratios of 1.96, 2.58 and 3.29, respectively.

In all cases the chimpanzee shows a significant difference from the orangutan when juvenile data are included. Only the adult group in *palate length* vs. *biporionic axis-prosthion minus palate length* is aberrant. This trend of similarities and differences is almost diametrically reversed when the same comparisons are made between the chimpanzee and the gorilla. In the latter pair only the *palate length* vs. *biporionic axis-prosthion minus palate length* is greatly different. (The same measurement taken to include juveniles, barely significant at the .05 level, is the minor exception.)

The gorilla and the orangutan when compared show highly significant differences in their *cranial breadth* vs. *bizygomatic breadth* and *nasion-basion* vs. *nasion-prosthion* rates, thus clearly allying the chimpanzee and gorilla with regard to the developmental patterns exemplified by these two pairs of measurements. The similarity of the muzzle growth rates of the gorilla and orangutan is most likely dependent upon the large size ultimately reached by the two animals. It should also be remembered that the sample size for either of the big apes was not large. It is, in fact, remarkable that so clear a distinction does occur in two significant measurements.

The affinity between the gorilla and the chimpanzee can also be demonstrated by simulating lineage allomorphosis with neontological data, representing in addition to the three forms utilized above, specimens of the pygmy chimpanzee, *Pan paniscus*, and the mountain gorilla, *Gorilla g. berengei*. Such procedure is a special application of genus-form allomorphosis. It should be emphasized that, in contradistinction

to adult allomorphosis, neither genus-form allomorphosis as used here nor true lineage allomorphosis has anything to do with the growth of the individual. Lineage allomorphosis is usually demonstrated in a paleontological series, such as Robb ('35) for a horse phylum. Fossil adults at different evolutionary levels are taken to represent average individuals of the populations from which they were drawn, and the rates of change in various dimensions may show allometric relationships. The coefficient for heterauxesis may coincide with that for lineage allomorphosis in the few cases where it can be measured, though Lull and Gray ('49) found this untrue in the ceratopsian dinosaurs. In such cases adaptation has not followed patterns inherent in the individual's growth mechanism. In figures 1 and 2 for each measurement the mean has been plotted separately for both sexes of each species (*Gorilla g. berengei* male only).

In three of the 4 cases the line has been drawn that best represents the trend of the chimpanzees and gorillas. The wide divergence of the orangutan from this allometric line is especially noticeable in the *nasion-basion* vs. *nasion-prosthion* diagram (fig. 1). While not so marked, the deviation of the male orangutan is considerable in the charts for *palate breadth* vs. *palate length* (fig. 1) and for *palate length* vs. *biporionic axis-prosthion minus palate length* (fig. 2). No clear allometric trend was evinced by the *cranial breadth* vs. *bizygomatic breadth* plot (fig. 2), which is explicable if the allometric relationship holding between these two variables is a reaction to the increasing size of the jaw musculature. The sometime eccentricity of the female *Pan paniscus* may in part rest upon the fact that it represents but a single specimen.

Previously we have shown that the gross dimensions of the palate develop allometrically; as a final application of the technique the three bones comprising the palate complex have been analyzed separately. Baer ('54) has studied the loci of growth in rats by vital staining (alizarin red S), and found that individual bones in the cranium are the units of growth. He concluded that they present a physiologically valid subject for allometric study free from the possibility of confounding a number of different growth rates. Moore ('49) found in a juvenile macaque specimen by vital staining that the entire premaxilla was undergoing growth, while the palatine process of the maxilla and the palatine bone were growing only at the transverse suture.

In the present study measurements corresponding to these three segments were taken along the midline of the palate on the 35 juvenile

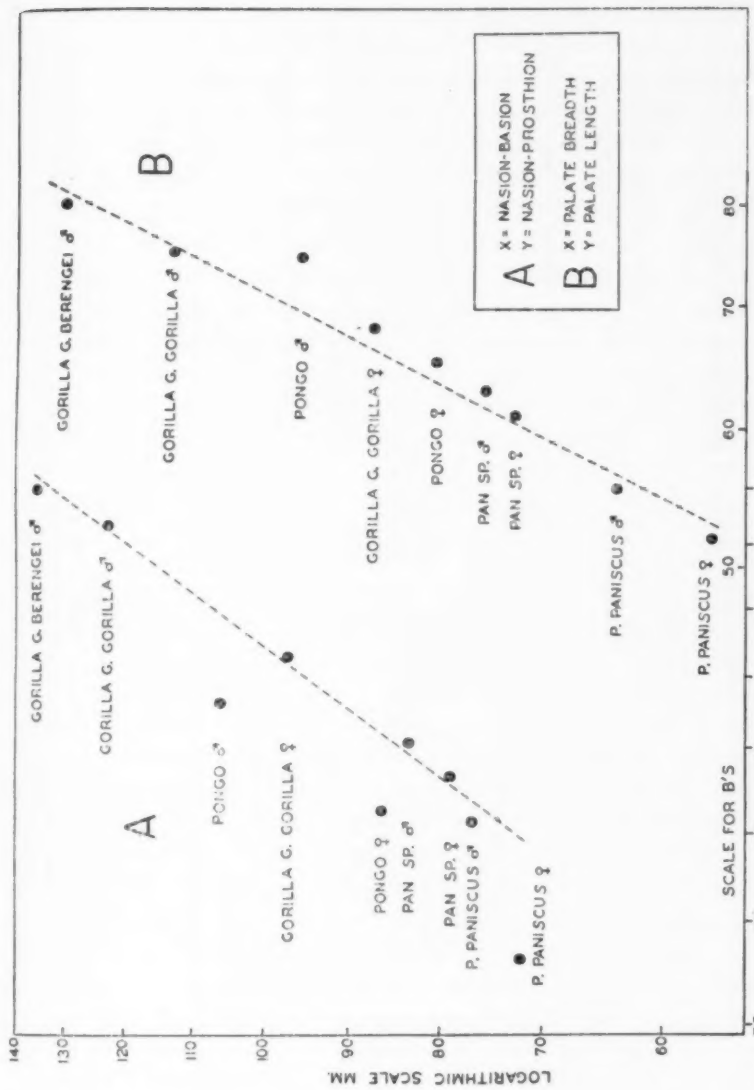

FIG. 1. Simulated lineage allomorphosis lines between chimpanzees, orangutans and gorillas based upon mean cranial measurements for *nasion-basion* vs. *nasion-prosthion* (*A*) and *palate breadth* vs. *palate length* (*B*).

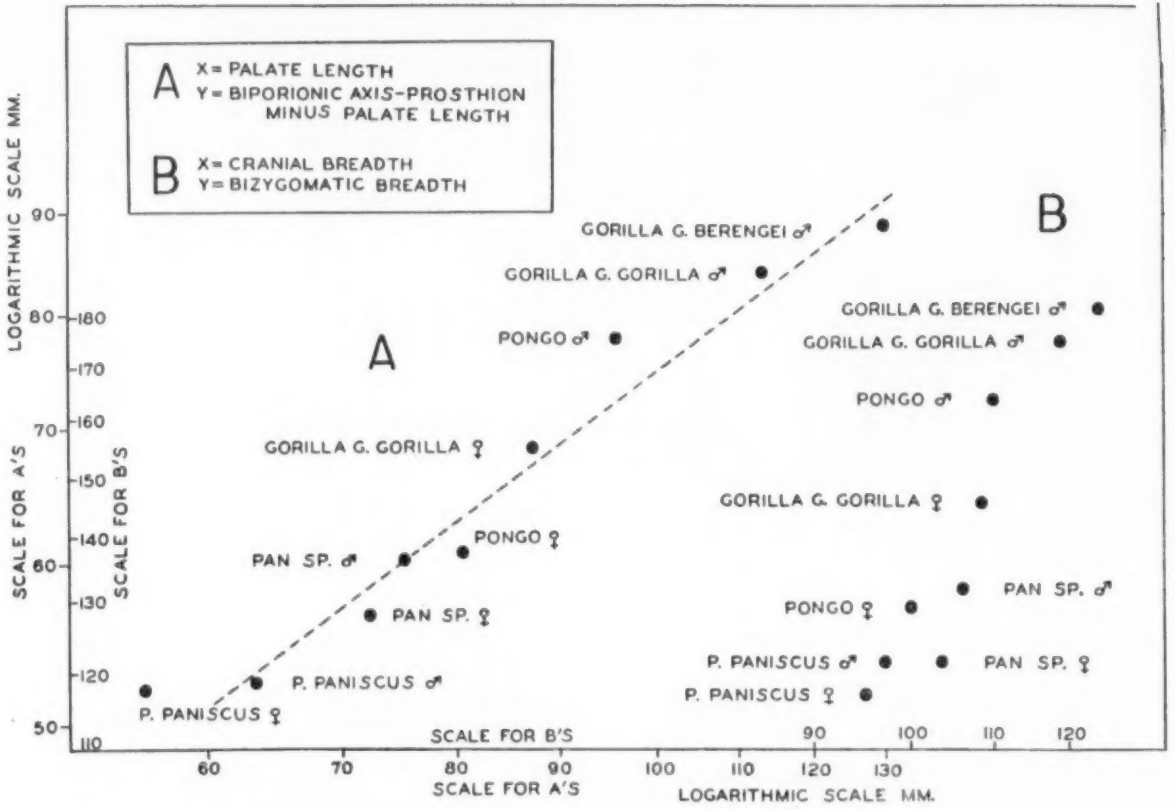

FIG. 2. Simulated lineage allomorphosis lines between chimpanzees, orangutans and gorillas based upon mean cranial measurements for *palate length* vs. *biporionic axis-prosthion minus palate length* (*A*) and *cranial breadth* vs. *bizygomatic breadth* (*B*).

chimpanzee specimens. Orthographic representation of these data indicates that increases in the premaxilla and the palatine are roughly commensurate, while the increase of the maxillary portion is much greater than either of the others.

Huxley ('32) and Clark and Hersh ('39) have discussed allometric growth gradients in segmented regions of an animal, such as lobsters' chelipeds. If the palate is considered in a similar light, the growth of each segment can be related to that of the whole palate minus its own contribution. For the 35 immature chimpanzees the premaxilla has a k value of 0.751, the maxilla, 0.968 and the palatine, 2.309. The palatine may be reacting to growth of the posterior pharyngeal musculature in a way similar to that suggested for the growth rate of the zygomatic arch. Both the premaxilla and the maxilla differ significantly from the palatine, but not between themselves. It would appear then that a relative growth gradient exists in the palate and that the rates of growth are of decreasing magnitude anteriorly.

CONCLUSIONS

The application of allometry as a tool suitable for morphological work in physical anthropology is heightened by the precise nature of relative growth rate comparisons which it makes possible. And because it is exponential, it provides a much more flexible methodology than proportions. It is also possible that applications long current in paleontology may become feasible with the increase in fossil primate material.

Systematic groupings cannot, of course, be dependent upon a single classificatory criterion. But close similarities in growth patterns should be given more weight than secondary characteristics such as pelage differences or skeletal rugosity traceable to large muscle attachments, certainly so if phylogeny is stressed in the taxonomic scheme. Allometric relationships found by Lumer ('40) in the domestic dog indicating certain ancestral stocks suggest the utility of differential growth analysis even in such an exaggeratedly variegated species. The present study shows a close affinity between the gorilla and the chimpanzee as opposed to the orangutan, based upon allometric similarities in two analyses quite different in nature.

It is interesting to note that two of the dimensions which best show the difference between the gorilla and chimpanzee on the one hand and the orangutan on the other are those which in the individual allomorphosis lines show no significant difference between the adults and the

porionic axis-prosthion minus palate length (A) and cranial breadth vs. bizygomatic breadth (B).

juveniles (see table 3). This perhaps suggests that the apparent differences in these categories between the chimpanzee and the gorilla are due to similar ontogenetic growth patterns having been at some stage of evolution (so to speak) allowed to manifest different terminal overall morphological configurations through the mechanism of general body volume increase.

A much less certain indication of this is found by comparing the k values previously given for heterauxesis and adult allomorphosis with those determined for the three cases of genus-form allomorphosis (tables 2 and 3). In the three cases the genus-form allometric lines conform more closely with those found for heterauxesis in the chimpanzee. The results are contradictory for the gorilla and orangutan, but the juvenile samples of these two groups are too small to be completely reliable. Since heterauxesis and genus-form allomorphosis differ in kind, no statistical test can be made to determine the significance of this tendency.

Scott ('51) has recently reviewed the question of the process of maxillary growth, noting two general views: one, that the forward growth of the maxilla is primarily the result of sutural growth at the back of the maxilla; and two, that the forward growth is largely anterior apposition.

Scott ('48) elsewhere has noted that the ostium of the antrum in the maxilla appears to be a relatively fixed point (at least in the human being) upon which to base maxillary measurements. However, the use of this landmark in measuring the chimpanzee was found to be incompatible with maintaining undamaged calvaria.

If the palatal growth gradient adduced above has any bearing on the question of forward jaw growth, it would indicate that the premaxillary is less of a center of active growth than the maxillary, which in turn seems to predicate at least a moderate amount of sutural growth in this region.

SUMMARY

The technique of allometry, fitting the formula $y = bx^k$ to morphological variables, has been applied to measurements taken from a sample of 170 chimpanzee, orangutan and gorilla calvaria. Using four basic pairs of cranial measurements—*palate breadth* vs. *palate length, cranial breadth* vs. *bizygomatic breadth, nasion-basion* vs. *nasion-prosthion,* and *palate length* vs. *biporionic axis-prosthion minus palate length*—relative rates of cranial growth in the great apes were investigated. The use of allometry instead of proportions, as a much more flexible measure of

morphological change during growth, has been discussed, as has its possible application to the measure of adolescent growth spurts. By the use of both allometry of growing individuals and interspecific allometry of adult forms, the gorilla and chimpanzee have been shown to be much more closely related and mutually distinct from the orangutan than the usual tripartite taxonomic classification indicates. The evidence presented suggests that the allometric growth patterns in the chimpanzee would, given an over-all size increase, produce results quite similar to the exaggerated osteological morphology of the gorilla. The palate complex was analyzed with reference to the recent discussions concerning the mode of maxillary growth, and the results would indicate a greater degree of sutural growth than often is allowed.

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RELATION BETWEEN HAIR COLOR AND METALS IN HUMAN HAIR

BY HIDEO KIKKAWA

Department of Genetics, Faculty of Medicine, Osaka University, Osaka, Japan

INTRODUCTION

SINCE olden times, hair color of human beings has attracted much attention in both the literary and scientific fields. In both cases, however, descriptions of hair color have always been represented by such general terms as white, yellow, red and black, or by special expressions such as blonde and brunet. These are not very satisfactory to scientists, who therefore have felt the need for some other way of describing, which will be advantageous in many respects. Recently we have found a new way, though we must admit that it is still incomplete. This method is based on the fact that there is a certain relationship between hair color and the type and amount of metal contained in the hair (Kikkawa, Ogita and Fujito, '55).

I wish to report in this paper some analytical results which were obtained on new samples of human hair, in addition to data previously published in *Science*.

Before going further, I wish to acknowledge with gratitude the kindness of Dr. G. W. Lasker, who sent me samples of human hair. I am also very grateful to Messrs. Z. Ogita and S. Fujito of this laboratory, who have helped me in many ways.

MATERIALS AND METHODS

Several samples used in this paper were obtained from a barber at Kobe in Japan, where most of the customers are foreigners. A few samples were obtained from myself and from my acquaintances. The rest were selected from the samples sent by Dr. Lasker.

TABLE 1

Metal Patterns of Human Hair of Different Colors

SAMPLE	HAIR COLOR	SOURCE	METAL-PATTERN *					
			Fe	Mo	Cu	Co	Ti	Ni
A	Reddish yellow	White race (English origin, ♀, 17 years old)	2	2	1	0	3	3
B	Yellowish red	The same (23 years old)	2	1	1	0	3	2
C	Dark brown	White race (Baltic, Russian and Jewish origin, ♀, head hair)	3	1	3	2	0	2
D	Reddish dark brown	The same (leg hair)	3	2	2	2	0	2
E	Reddish brown	White race (Scotch and Dutch origin, ♀)	3	3	2	0	0	1
F	Dark brown	White race (German, French and English origin, ♀)	3	2	2	0	3	2
G	Reddish black	White race (Greek origin, ♀)	2	3	3	2	0	1
H	Grey	White race (Origin unknown, old ♂)	1	0	1	1	1	4
I	Yellow	White race (Origin unknown, ♀)	2	2	1	1	4	3
J	Reddish brown	White race (Origin unknown, ♀)	3	3	2	2	0	1
K	Black	Black race (American Negro?, ♂)	3	0	4	1	0	2
L	Reddish dark brown	White race (Origin unknown, ♀)	3	2	2	2	2	1
M	Reddish black	Swedish and Japanese parentage, ♀)	3	1	2	2	0	2
N	Black	Yellow race (Japanese, ♂)	3	0	2	2	1	2
O	Grey	Yellow race (Japanese, old ♂)	1	0	1	1	0	4

* Grades: 0, not or scarcely detected; 1, detected slightly; 2, detected moderately; 3, detected distinctly; 4, detected very distinctly.

The types and amounts of metals were examined largely by the paper-chromatographic method shown in our previous paper (Kikkawa *et al.*, '55). In this method, the analysis of metals can be determined with a very small amount of hair for one sample (30-100 mg). But, for a rigid quantitative analysis, a greater quantity of each sample must be patiently ignited by dry oxidation or by wet oxidation with the use of H_2SO_4, HNO_3 or $HClO_4$. After the treatment, the solution is fractionated by diphenylthiocarbazone (dithizone) dissolved in carbon tetrachloride under a fixed condition of pH. Then, to each fractionated solution is added an adequate organic reagent such as *o*-phenanthroline, dimethylglyoxime and nitroso-R salt, *etc.* Comparing the color of the test solution with that of a standard one, the amount of each metal can be estimated (Parks, Hood, Hurwitz and Ellis, '43; Sandell, '50). The results shown in table 3 were obtained by these procedures.

RESULTS

Figure 1 and table 1 represent results of 15 samples which were obtained from 13 different individuals.

As shown in our previous paper, there is a certain relationship between hair- or skin-color of mammals and types of metals, as indicated in table 2.

TABLE 2

Relationship between Hair or Skin Color and Type of Metal

COLORATION	ASSOCIATED METALS
White	Ni
Yellow	Ti
Red	Mo
Blackish	Cu, Co, Fe

Namely, white color is associated with nickel, yellow with titanium, red with molybdenum, and blackish with copper, cobalt and iron. Based on these findings, we have proposed the hypothesis that hair and skin color of mammals may be composed of metallic complex salts which are coordinated with tyrosine derivatives. Even supposing that this simple assumption is refuted or modified in future, the relation between hair and skin colors and types of metals will remain as a fact. This relation has been ascertained in the present experiment, too. Namely, white hair

contains Ni in abundance, in either the white or the yellow race (H and O in fig. 1 and table 1). Judging from these facts, I am safe in the surmise that both D. Eisenhower and N. Khrushchev have abundant nickel in their grey hair.

In yellow hair like A, B and I in fig. 1, titanium is contained in plenty, and the amounts of copper and cobalt are very scarce. From this, it may be concluded that the golden hair of Marilyn Monroe is rich in titanium rather than gold.

Reddish hair like E and J contains molybdenum in abundance, and blackish hair is rich in copper, cobalt and iron, in both the white and the yellow races, and even in the offspring of marriages between them (M). But, it is of interest that the black hair of the Negro (K) contains great amounts of copper and iron, and a very little amount of cobalt, though this result has been ascertained only for one sample.

Now, some interesting points observed in figure 1 and table 1 will be taken up. Sample A represents the hair of a 17-year old girl of the white race and its metal-pattern, and B represents those of the same person at 23 years of age. Both kinds of hair are very alike in color, but A is slightly more reddish than B. Metal-patterns of A and B are also very similar with each other, but the former seems to contain slightly more molybdenum than the latter.

Sample C represents the head-hair of a 32-year old woman belonging to the white race, and D is the leg-hair of the same person. Apparently, D is paler than C in color, and the difference is clearly shown in their metal-patterns, *viz.*, the content of copper in D is less than that in C.

Thus, the metal-pattern varies according to the change of coloration, even in the same person. The most distinct difference may be found in an individual having two types of hair-color like black and white. Figure 2 represents the result obtained from the author's own hair.

Small quantities of black and white hair were picked from my head, and equal amounts (100 mg) of the two kinds were ashed separately. As shown in this figure, white hair contains only nickel in abundance, whereas black hair is rich in copper, cobalt and iron, but contains little nickel. This fact reveals clearly that there is a close relation between the hair-color and the type and amount of metal contained in the hair.

In this paper, as described before, no detailed quantitative analysis was performed. But, in table 3, I have shown for the reader's reference, some data published previously in *Science*, supplementing them with a

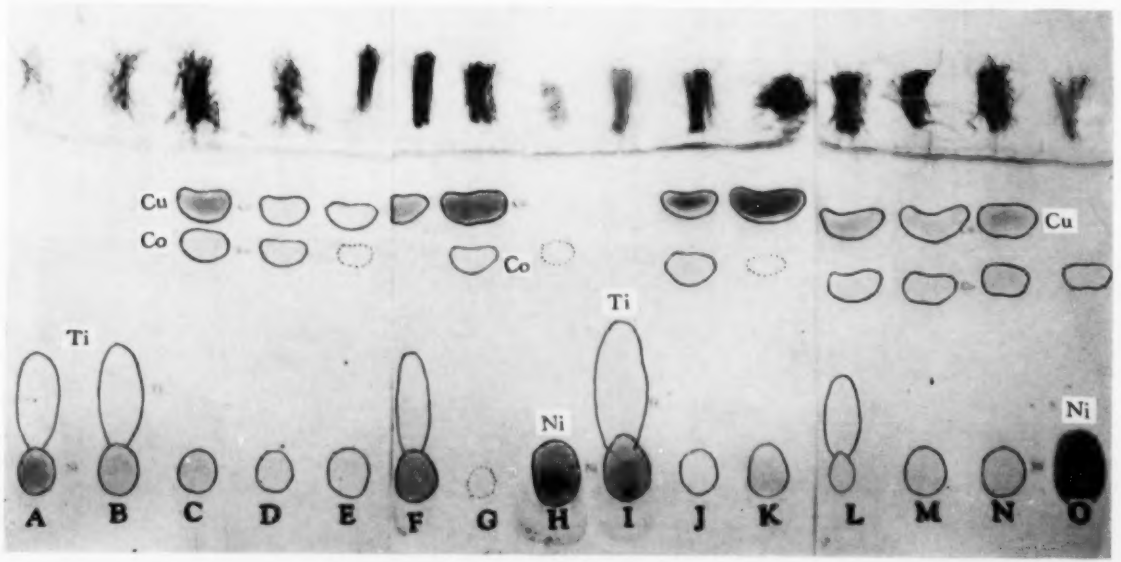

FIG. 1. METAL ANALYSES OF HUMAN HAIR.

Samples of human hair of various races and their metal-patterns analyzed by paper-chromatography (see table 1 and the text).

Solvent: Acetone-Butanol-HCl (5: 2: 1).

Reagent: For Cu, Co and Ni, 0.5% rubeanic acid dissolved in 98% ethanol was employed; for Ti, 1% pyrocatechol dissolved in water. In these conditions, however, the detection of Fe is very difficult and that of Mo is impossible. For Mo, 1% potassium ethylxanthogenate dissolved in water was used, but the color faded within an hour. As another method of detecting Fe, Ti and Mo, a supernatant layer of a mixture (butanol 4 + acetic acid 1 + H_2O 5) was employed as a solvent, and 1% yellow prussiate of potash dissolved in water was used as a reagent under acidic state. The results shown in table 1 were obtained by these combined procedures.

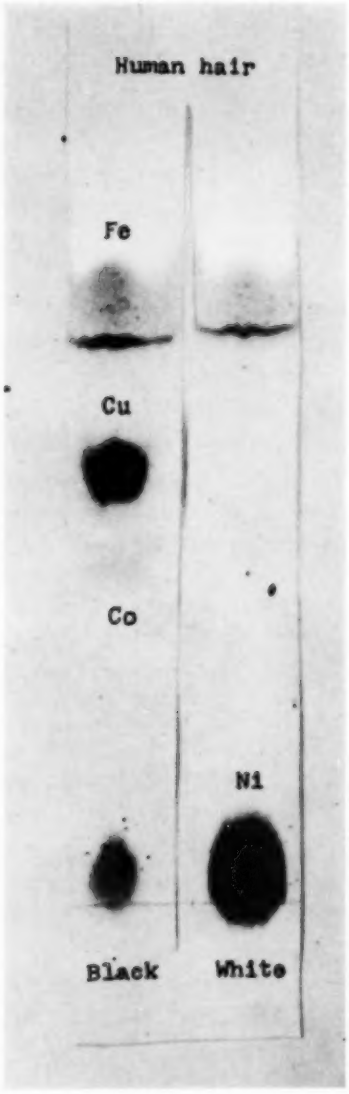

FIG. 2. A paper-chromatogram showing the metal-pattern of black hair (left) and of white hair (right), both of which were obtained from the author himself (see the text). Solvent: Acetone-Butanol-HCl (5: 2: 1). Reagent: 0.5% rubeanic acid dissolved in 98% ethanol.

few additional results. In general, the quantitative results fully accord with the results obtained by paper-chromatographic methods.

TABLE 3

Metals Present in Human Hair (μg/10 g of fresh hair)

COLORATION AND ORIGIN	METALS *					
	Cu	Fe	Co	Ni	Ti	Mo
Blonde (Caucasian)	60	11	0	7	120 **	3
Median brown (Caucasian)	80	68	11	19	6	9
Black (Mongolian)	190	290	6	13	—	3
Grey *** (Mongolian)	84	12	—	33	—	—
Black (Negro)	310	200	0	3	0	0

* The ashing was performed by dry oxidation except Ti in Blonde.
** The result obtained from a different sample.
*** Hair mixed with *ca* 70% white and 30% black.

DISCUSSION

Although there is little doubt that the hair color of human beings is determined genetically, the mode of inheritance is very complicated and no definite conclusion has yet been obtained (Davenport and Davenport, '09; Reed, '52; *etc.*). This complexity may be forecast from our studies based on inorganic chemistry, because even at the present stage of research, we are aware of the fact that 6 or more types of heavy metals are concerned with the pigmentation of hair and that their amounts are also responsible for the grades of coloration. Thus, various combinations of these metals, in either types or amounts, may result in very complicated hair colors, and it is easily conjecturable that genetical analyses in such circumstances would be very difficult. In future, however, this difficulty may be overcome to some extent by analyzing metal-patterns of hair in persons who belong to one lineage. Actually, some pioneer investigators have already noticed the phenomenon that if the colors of human hair are different from one another, there is also found a divergence in the types and amounts of the metals contained in the hair (Rothman and Flesh, '43; Flesh and Rothman, '48; Flesh, '48; Smyth, Porter and Bohren, '51).

SUMMARY

Human hairs of various races have different types and amounts of metals, according to the coloration. There is a certain relationship between hair colors and metals, *i. e.*, white color is rich in nickel, yellow in titanium, red in molybdenum, and black in copper, cobalt and iron. When the hair color changes with age or area of the body, the metal-pattern varies accordingly.

ADDENDUM

After this manuscript was submitted, Goss and Green (1955, *Science*, *122*: 330-331) obtained an opposite result: that white hair in animals contains more copper than does black. In fact, an improper wet oxidation frequently gives a result similar to that obtained by Goss and Green. But, by an improvement of methods of dry and wet oxidations, it was found recently that the metal contained in mammalian hair is more abundant than expected. For example, black and white hair of the guinea pig gave the following results (p. p. m. of washed dry hair): black, Cu 268, Co 263, Ni 96; white, Cu 87, Co 38, Ni 638. The details will be published in *Science*.

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FORCE ANALYSES OF HORIZONTAL TWO-HANDED PUSHES AND PULLS IN THE SAGITTAL PLANE [1]

BY GEORGE R. L. GAUGHRAN AND WILFRID TAYLOR DEMPSTER

Department of Anatomy, University of Michigan, Ann Arbor

THIS research was undertaken to elucidate the mechanical factors which are operative when the body exerts pushes and pulls with the hand. No evaluations of the mechanics of body action in this respect are now available. A number of investigators have, of course, measured the magnitude of push and pull forces under various conditions. It has been tacitly assumed that the identification of those postures and movements which will produce maximum operating forces should aid in determining optimum positions of a foot rest, back rest, or hand grip and thus increase the efficiency of man-machine systems. Hand forces have been studied by Lehmann ('27), Garry ('30), Bedford and Warner ('37), Hugh-Jones ('45), Müller and Müller ('49), Wakim *et al.* ('50), and Hunsicker ('55); foot pedal forces by Müller ('36), Koch ('41), Clark and Weddell ('44), Martin and Johnson ('52), and Rees and Graham ('52); and hand and foot pedal forces by Hugh-Jones ('47), Orlansky and Dunlap ('48), and McFarland *et al.* ('53).

On the whole the approach to these studies has been direct, and the resulting data have been empirical. The transfer of derived experimental values even to situations that are apparently related is uncertain, since the principles of body mechanics involved have not been clear.

We are prone to regard all forces which the subject produces as direct muscle force and to neglect completely the inertia of body dead weight in the effort. The position of body mass relative to its support area affects the body anchorage and hence the efficiency of muscular effort. Either the anchorage or the muscular effort may be the limiting

[1] A study conducted under contract with the Wright Air Development Center, (Section of Anthropometry) Air Research and Development Command, United States Air Force, Wright-Patterson Air Force Base, Ohio.

factor which defines the maximum force that the body produces. This is an area which calls for critical attention.

Although our evaluation of the mechanics involved can be little more than an introduction to one class of problem in force relationships, the approach, nevertheless, should point to certain of the fundamentals involved in the application of forces by the body. This study brings to light two basic mechanisms of force production. First, when the trunk is firmly braced against the back of a seat, hand or foot pushes may be exerted as direct compressive forces spanning the hand grip (or foot pedal) and the back rest. With a suitable shoulder harness hand pulls may be exerted as a direct tension between the hand grip and the harness (and its attachments). Second, push or pull forces ordinarily involve the action of force couples; body dead weight when applied at different points on a support creates variable leverages and appreciable torque values. The analysis of the latter mechanism using the principles of rotational mechanics will be the concern of much of this paper.

In the method employed we endeavored to avoid complicated asymmetrical patterns of activity. The method was simply that of having test subjects exert balanced two-handed forces in the sagittal plane and measuring all significant forces which operate in that plane. The problem was to be treated as one involving the balanced forces of statics. To simplify, the subjects initially were symmetrically placed upon a seat without back or foot rests and they exerted steady horizontal push and pull forces in the midsagittal plane. The aim was to determine how the body mass, exerting a vertical component, was used to effect horizontal push and pull forces. Later the influence of foot and back rests was considered.

The human body is composed of a series of articulated links—the extremity segments, thorax, head and neck, etc. Bones form the rigid support for the segments and motions at the joints are rotatory rather than translational in character. (In this study, however, static postures alone are considered and problems of movement are ignored.) Each of the body segments has mass which is subject to the vertical influence of gravity; the degree of this attraction is expressed by the term "weight." The segmental masses, moreover, can be assumed to be concentrated along the respective links at the segment centers of gravity. Thus, for purposes of static analysis, we can visualize a body composed of segmental masses as a related system of vertical force vectors (arrows

of fig. 1) which intersect the horizontal at different points. The sum of these segment masses exerts a downward force acting through the common center of gravity of the body; this vector (W of fig. 1), the balance point of the vertical force vectors, is located by a balancing of moments. When segments move to a new position, their masses acquire

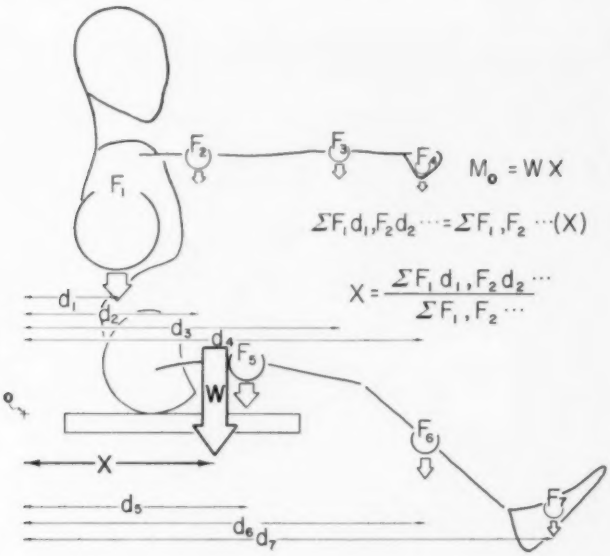

FIG. 1. The distribution of mass in a symmetrically seated individual. A stick figure shows the relative masses ($F_1, F_2 \cdots$) of body parts located at their respective centers of gravity; the vertical lines of action are represented by arrows and are located at varying distances ($d_1, d_2 \cdots$) from some arbitrary point (0). The heavy arrow (W) represents whole body mass acting at the center of gravity, a distance of X from point 0. Mo is the moment of rotation about point 0. The formulae represent one method for determining the location of the whole body CG line.

new positions in space, and both the location of the vertical force vectors of the segments and that of the whole body center of gravity change. Apart from minor shifts of blood within the blood vessels of different regions, the segment masses may be regarded as constant from moment to moment.

Actually a true balance of forces over a period of time is only approximated. Maintenance of a posture for a protracted period involves irregular volleys of muscular activity and the degree of steadiness

depends upon how the forces fluctuate. In mere standing, for instance, the center of gravity of the body sways erratically over the support area with variations according to subject (Hellebrandt *et al.*, '37, '42). Even though these periods of maintained posture truly involve dynamic behavior of muscles, the mean posture may be studied helpfully by static methods. The instantaneous posture record shown in a photograph may

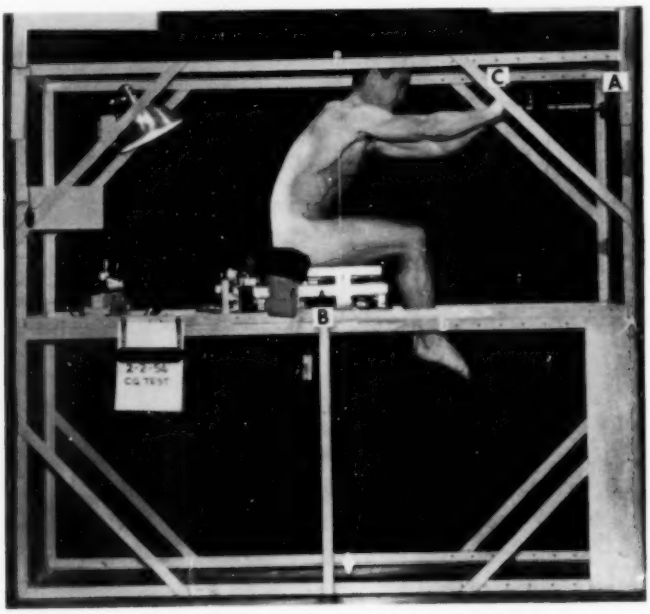

FIG. 2. Photograph of a subject seated in the apparatus and exerting a horizontal midsagittal push at shoulder level. This type of photo was taken for each test at the moment of maximum horizontal force (recorded by gauge labeled A). A spirit level (C) attached to the adjustable bar for force application assured a truly horizontal force vector. A metal frame (B) formed the middle layer of a trilaminate seat.

be analyzed statically, and such analyses have value, if the photographed posture is representative of some mean body position.

APPARATUS AND METHOD

To produce records for force analysis, a subject, unclothed, sat symmetrically upon a horizontal seat set in the middle of a rectangular framework (fig. 2). He exerted a maximal steady horizontal push or

pull at shoulder height with both hands. At the moment of maximum effort the magnitude of the hand force was noted on a dynamometer and simultaneous photographs were made to record: (1) the subject's posture seen side view, (2) the dials of dynamometers which recorded horizontal reaction forces at the seat, and (3) the dials of other force gauges which showed the distribution of force at the front and rear of the seat. Several arbitrary body postures involving variations in the distribution of the segment masses formed the experimental variable. To reduce individual variability in the record for each posture 10 repetitions were made so that an average could be obtained; all procedures were repeated on three different individuals.

Figure 2 illustrates the basic apparatus. At the upper right of the rectangular frame a horizontal bar supported a 100 kg compression gauge (A) or a 200 lb tension gauge which recorded hand pushes or pulls, respectively. Horizontal bars at the mid-height of the frame supported the basal part of the trilaminate seat. Upon this a rectangular, metal seat frame (B) was supported near its corners by four Dillon pressure gauges, each of 100 kg capacity. These gauges collectively recorded the weight of whatever mass was superimposed; different readings implied an asymmetrical distribution of mass. The seat board, covered by a rubber friction-mat, formed the uppermost lamina.

In figure 3 (right) the seat board has been raised above its basal support to show the four dynamometers (with dial gauges) placed near the corners of the frame which they support. At the sagittal margins of the upper surface of the metal frame, metal channels carried several ½-inch ball bearings. The seat board, which also has metal channels along the lateral edges of its lower surface, rested on the ball bearings. These permitted the seat (upper lamina only) to slide freely in a fore-and-aft direction; free fore-and-aft movement, however, was entirely eliminated by two horizontal mounted pressure gauges (A and B) which are attached to the metal frame.

Forces on the seat acting forward were recorded on the front gauge; backward acting vectors were recorded on the rear gauge. Readings of the 6 seat gauges were recorded directly or through 45° mirrors by two 35 mm Argus cameras, which were activated by solenoids. About 80 lb of lead weighting was attached near the rear edge of the seat surface to prevent forward seat tilting in certain subject postures.

The subject was required to sit on the seat, and for each man the hand-dynamometer height was adjusted to shoulder level. Six pull and

6 push positions were planned for each of the three subjects. In all instances the subject exerted all the force of which he was capable through a symmetrical two-handed push or pull in the mid-sagittal plane. The hand-dynamometer distance varied with subject posture and to this end a series of 6-inch and 3-inch lengths of ¾-inch pipe were coupled to a T-shaped grip for the application of push and pull forces; a spirit level and mirror (C, fig. 2) were mounted on the bar, so that

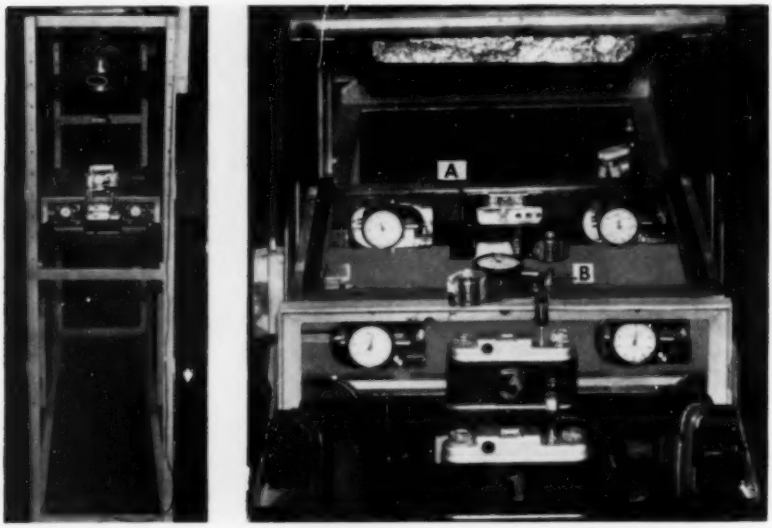

FIG. 3. Left photograph is an overall end view of the apparatus. At the right, a close up end view, the top layer of the seat has been raised to show the middle lamina formed by the metal frame resting on four dynamometers located at its corners. A and B are gauges which recorded fore-and-aft horizontal counter forces at the seat. In the foreground are cameras (1 and 3) which photographed the dials of the 6 seat gauges.

the subject could be certain of a truly horizontal force. At least 10 records for each posture were required for a full routine; hence, a minimum of 120 records were available on each subject. To avoid fatigue effects, 24 records or less were made at each appointment.

When the subject was in position for a maximum effort for any posture, an observer watched the hand-dynamometer dial and when the gauge reached a maximum, the operator took an overall side view photograph of body position (like that of fig. 2) using a 120 mm Ciroflex camera, and through the solenoids he made simultaneous records of the

6 seat gauges. Thus, for each test, at the moment of maximum push or pull, there were records on: (1) the force of hand push or pull, (2) the horizontal counterforce at the seat, (3) the distribution of the subject's weight at the front and rear of the seat, and (4) an overall side view record of the subject's posture.

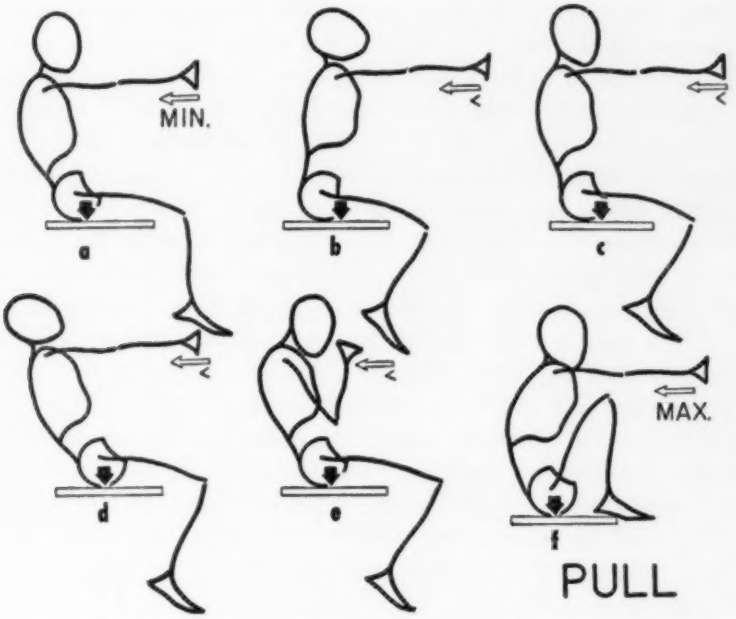

FIG. 4. Stick figures representing 6 test positions assumed by the subject in exerting pull forces arranged in order of force application from minimum at the upper left to maximum at the lower right. The arrows above the seat represent the relative location of the force vector exerted by body mass.

The side view photographs were enlarged and traced on translucent sheet plastic. By superimposing these tracings for all repetitions of a given posture the variations in position and an average position could be determined.

SUBJECT POSTURES

In figure 4 the positions shown as stick figures represent 6 standard seated postures, selected to obtain different patterns of body mass distribution consistent with a fixed height of pull. The vertical line of action of the center of gravity of the body (*vide infra*) is represented

in each sketch by the arrow above the seat. The sequence of postures corresponds with the relative strength of pull (min. upper left to max. lower right); in contrast, the relative closeness of the center of gravity of the body to the rear edge of the seat most commonly followed the sequence a-f-e-d-c-b. Occasional variations in this sequence due to differences in individual posture and seat contact positions offered no difficulty, since each force test was actually analyzed individually and the location of the center of gravity was known in each instance.

The postures of figure 4 were as follows. At "a" the subject leaned back passively while holding the hand grip; the center of gravity was well toward the rear. Next, at "f" both the buttocks and the feet contacted the seat, and the doubled up posture was strained; the center of gravity was nearly as far back as at "a." At "e" the subject's trunk was tensed, his arms were flexed and held close to the body, and his knees were tensed and bent; the center of gravity was more forward in this posture. Sketch "d" shows a posture in which the center of gravity was only a little farther forward; the trunk was tensed and strongly inclined backward; and the knees were bent sharply. At "c" the subject sat upright in a strained position with the legs sharply flexed; the center of gravity was a full three centimeters farther forward than in the last position. Finally, at "b," the most forward position of the center of gravity, the subject leaned as far forward as he could and still be able to exert positive pull values.

Figure 5 shows the standard push positions in a sequence of weak to strong values. The mass distribution was superficially comparable with that of the pull positions; there were, however, certain differences in leg and trunk posture, as shown, which the subjects characteristically introduced to facilitate push force. When the original procedures were set up, the 6 pull and 6 push postures were assumed to be identical; later analyses showed that trunk and leg tensions altered the postures in the ways shown in figures 4 and 5. The positions of the centers of gravity shown were based on precise measurements and calculations of moments.

A mechanical analysis of the force system of our tests necessitated a determination of the subject's center of gravity and of the reciprocal vertical reaction force acting upward at the point of effective seat contact. The data for at least 10 repetitions of each posture were averaged and these average force values were used in the calculations of centers of gravity, effective seat contact, and moments of rotation.

The center of gravity was calculated by determining the sum of the moments about the seat contact at the rear pressure gauges. This point (A) is shown in the diagram of the force vectors present in the system (fig. 6). The sum of the moments about A (ΣMA) when the subject

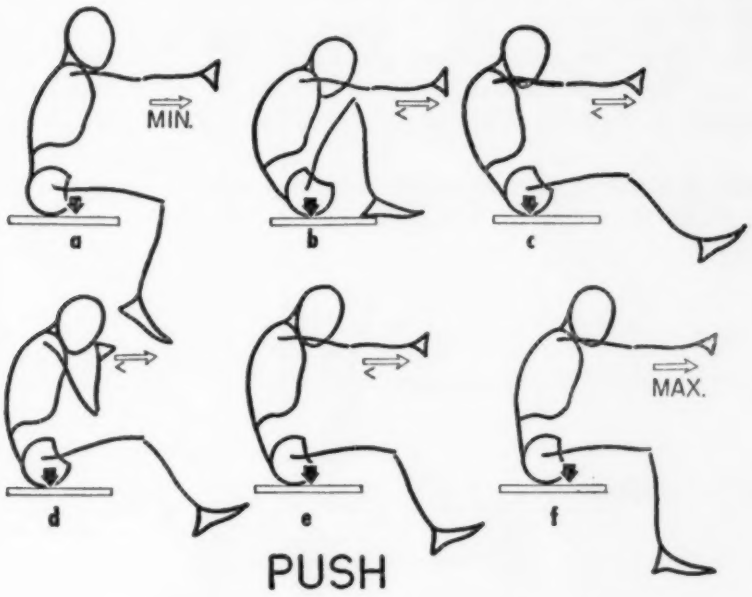

FIG. 5. Stick figures representing the 6 positions assumed by the subject in exerting push forces arranged in order of force effected from minimum at the upper left to maximum at the lower right.

pulls is: $Wx_2 + F_4h - F_2d$, which, since the system is in equilibrium, equals zero. From the above equation distance x_2 is obtained:

$$x_2 = \frac{F_2d - F_4h}{W};$$

this gives the location of the center of gravity relative to point A. Applying a similar analysis to push situations we arrive at the formula:

$$x_2 = \frac{F_3h + F_2d - F_5b}{W}.$$

Locations of the body center of gravity were checked through the use of cadaver data on the location of segment centers of gravity and on

measures of body bulk made on the three test subjects using techniques of limb immersion and a pantograph-planimeter method for measuring trunk volume (Dempster, '56).

The locations of centers of gravity in body segments were known

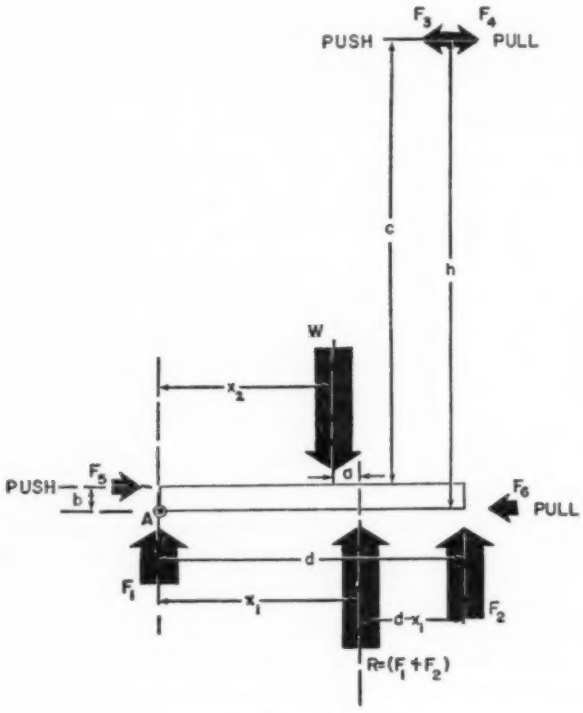

FIG. 6. Diagram of force vectors and moment arms present when the seated subject, without foot or back rest, exerted a two-handed horizontal force in the midsagittal plane. *W* is the mass of the subject acting through the *CG* line and *R* is the reaction force acting upward at the point of effective seat contact.

from cadaver data (Braune and Fischer, 1889; Dempster, '56) and equivalent points were plotted as accurately as possible on enlargements of over-all side view photographs of the most nearly average posture in each group of 10 records of the test subject. Estimated masses of segments were based on volume measurements of the test subjects; these masses were assumed to be located at the points marked on the photograph. The whole body center of gravity represented a balance point around which these masses exert either a clockwise (—) or a counterclockwise

(+) moment. The moments of rotation were calculated by measuring the horizontal distances from some arbitrary zero point to the segment centers of gravity (fig. 1) and multiplying these distances by their respective masses. Since the force system was in equilibrium, the algebraic sum of the moments divided by the sum of the masses gives the distance of the overall center of gravity from the arbitrary zero point. To get the correct life-size scale, the measurements on the photograph were multiplied by a suitable correction factor. Results of the two methods of checking the location of body center of gravity were ordinarily within a few millimeters.

The point of effective seat contact (the location of vector R, fig. 6) was determined by equating the moments of F_1 and F_2 about R (*i. e*, $F_1x_1 = F_2(d - x_1)$ and solving for x_1:

$$x_1 = \frac{F_2(d - x_1)}{F_1}.$$

The significance of this factor will appear in the discussion of results.

GENERAL CHARACTERISTICS OF THE FORCE SYSTEM

In all of the postures muscular action holds the body members in a given spatial position. The individual segment masses are deployed in a characteristic pattern; a separate downward force vector acts at each segment center of gravity. For each posture the resultant force, *i. e.*, the whole body center of gravity, comes to have a specific location relative to the supporting surface. The average distances between the rear pressure gauge contact with the seat and the line of action of the body centers of gravity as calculated for subjects A, B, and C are shown in the second column of table 1.

If the sketches of figures 4 and 5 simply represented various positions of the subject without hand grip contact, the individual's mass would act downward through the center of gravity and would be opposed by an equal upward reaction in the same vertical line. Such a system would consist of two equal colinear forces acting in opposite directions, their resultant being zero.

In the actual push or pull situation, however, the location of the reaction vector, termed here the point of effective seat contact, is not in the same vertical line as the gravity vector. Figure 6 shows that this reaction vector is located at a distance of x_1 from the contact of the rear pressure gauges. The method of calculating for x_1 has been

TABLE 1 *

1	2			3			4			5		
PULL POSITION	DISTANCE IN CM FROM CG LINE TO REAR GAUGE-SEAT CONTACT			DISTANCE IN CM FROM EFFECTIVE SEAT CONTACT TO REAR GAUGE-SEAT CONTACT			HORIZONTAL DISTANCE IN CM FROM CG TO EFFECTIVE SEAT CONTACT			MAXIMUM HORIZONTAL MID-SAGITTAL PULL FORCE IN KG		
	Subject			Subject			Subject			Subject		
	A	B	C	A	B	C	A	B	C	A	B	C
a	24.0	22.8	22.3	27.3	28.2	27.7	3.3	5.4	5.4	3.6	5.3	6.2
f	24.1	24.3	19.8	41.7	44.1	42.0	17.6	19.8	22.2	18.8	19.3	22.8
e	26.0	26.4	28.4	41.9	44.2	42.3	15.9	17.8	13.9	16.9	17.3	14.2
d	26.5	25.8	24.5	41.8	42.7	41.3	15.3	16.9	16.8	16.4	16.5	19.1
c	29.8	28.8	29.4	41.4	43.7	42.4	11.6	14.9	13.0	12.4	14.6	13.3
b	30.3	29.2	31.1	41.9	42.9	42.3	11.6	13.7	11.2	12.4	13.3	11.4
PUSH POSITION										MAXIMUM HORIZONTAL MID-SAGITAL PUSH FORCE IN KG		
c	19.6	22.8	23.4	10.4	10.3	10.9	9.2	12.5	12.5	10.8	13.0	15.5
b	19.8	24.5	21.9	11.9	14.9	13.4	7.9	9.6	8.5	9.2	10.2	9.3
d	23.3	29.3	32.4	11.6	13.4	16.3	11.7	15.9	16.1	13.6	16.9	17.6
e	25.6	29.8	31.9	12.0	13.1	13.6	13.6	16.7	18.3	15.8	17.6	20.1
f	31.6	38.0	38.7	12.4	18.1	17.7	19.2	19.9	21.0	22.4	20.9	23.2
a	33.1	35.8	34.9	29.3	29.8	29.8	3.8	6.0	5.1	4.4	6.3	5.7

* Data obtained from experiments in which three seated subjects exerted maximum midsagittal, shoulder level, horizontal, two handed push and pull forces without the aid of foot or back rest.

considered above; the mean values obtained for this factor are listed in column 3, table 1. In pull position "a" (fig. 4) in which the subject grasped the hand grip and leaned back passively, the effective seat contact was close to the center of the seat. In all other pull positions, however, the subject strained backward and simultaneously applied his weight at a more forward position so that the location of the effective seat contact moved toward the front edge of the seat.

In push position "a" (fig. 5), the subject leaned forward passively against the hand grip; the effective seat contact was now several centimeters forward of the mid-point of the seat and behind the body center of gravity. In all other push positions the subject, as he pushed, concentrated his effort so that, in contrast, the point of effective seat contact moved toward the rear edge of the seat. The subject in pushing ordinarily extended the knees and flexed the thighs from the seat. Thus to produce a maximum force in pushing, he concentrated his effort so that the location of the effective seat contact was moved to the rear of the center of gravity; whereas to effect a maximum force in pulling, he concentrated his effort so that the location of the effective seat contact was moved forward of the center of gravity.

The subject's mass represents a vertical downward force vector acting through his center of gravity; an equal and opposing vector is located at the effective seat contact. These two opposing vertical parallel forces of equal magnitude in the same plane, but not in the same line, form a couple. When a force couple acts upon a rigid body the two opposed coplanar forces, separated by a finite perpendicular distance, cause rotation in their plane of action unless opposed by a couple of equal and opposite magnitude. A full discussion of forces, couples, and moments can be found in such texts on mechanics as Seely and Ensign ('45) and Timoshenko and Young ('40); the problem here, however, is one of applying the principles to the body system.

The couple formed by vertical forces is shown in the sketches of figure 7 by unshaded arrows. The figure at the right illustrates superimposed tracings of side view photographs of 10 repetitions of pull position "d" at the moment of maximum effort; the heavy outline shows the most nearly average position. In the sketch at the left, a wooden block has been substituted for the subject to simplify the force picture. The couple represented by the vertical force arrows tends to rotate the subject (or block) in a counterclockwise direction.

When the seated subject pulled on the hand grip, the dynamometer

recorded a horizontal force acting forward at shoulder level. In addition, a parallel force of equal magnitude acting in the opposite direction was recorded at the seat (solid black arrow in fig. 7). The two opposing horizontal forces at the hand and at seat level form a couple which tends to rotate the subject in a clockwise direction. The sense of this clockwise rotation due to the horizontal forces was opposed to that of the

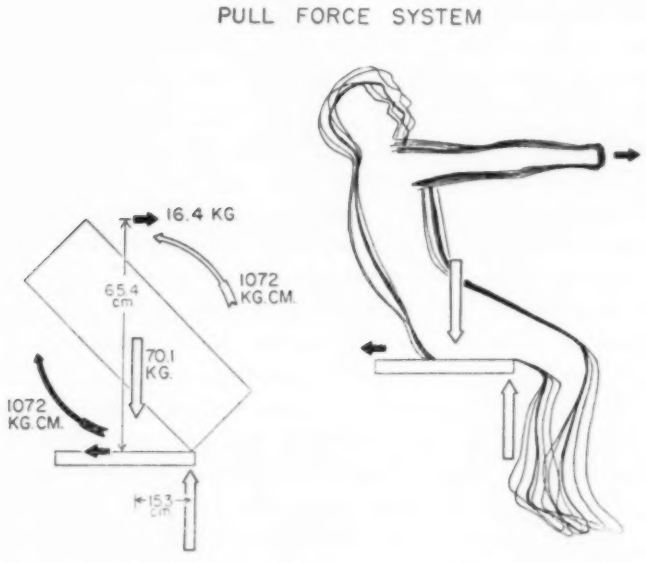

FIG. 7. At the right are represented body tracings of 10 repetitions of one pull position: the most nearly average outline is shown in a heavy line. The vertical forces are shown as outlined arrows and the horizontal forces as solid arrows. At the left a rectangular block has been substituted for the subject and the same force vectors are illustrated with the exact average values for their magnitudes and the average values of their moment arms. These forces form two couples, the moment of rotation of each being shown and the sense of rotation represented by the curved arrows.

vertical forces which simultaneously act on the subject (or block). The tendency of a couple to produce rotation is expressed by the term "moment of rotation" or torque, and its value is derived by multiplying the magnitude of one of the forces of the couple by the perpendicular distance between the two forces. The force and moment values calculated for the pull position illustrated at the right of figure 7 are also shown on the block diagram.

Figure 6 represents the type of reaction vectors recorded by hand and seat gauges. For a pull force, the horizontal vector recorded by the hand dynamometer, F_4, or its reciprocal, recorded by the seat dynamometer, F_6, multiplied by the perpendicular distance (h) between their lines of action gives the torque or moment of rotation produced by the horizontal couple. For a push force, the horizontal vector recorded by the hand gauge, F_3, or by the seat dynamometer, F_5, multiplied by the distance (c) between them gives the moment produced by the horizontal forces. The moment produced by the vertical couple is the product of the mass of the subject (W) or the reciprocal reaction at the seat (R) multiplied by the perpendicular distance between their lines of action (a).

It follows from the above that any body action which lengthens the moment arm of the vertical couple for a constant force will necessarily increase the moment produced by the horizontal couple. When the subject strains and adjusts his position of effective seat contact relative to his center of gravity in such a way as to increase the moment arm of the vertical couple, he simultaneously increases the pull or push force at a fixed height above the seat. Analyses of each of the standard pull postures showed the same qualitative relationships recounted here for the one posture figured.

Figure 8 presents a similar analysis of push position "f"; the central outlined figure of the sketch at the right is the most nearly average position, and the stippled halo about this figure represents the range of position for 10 push repetitions. A block diagram analogy of this push posture appears at the left. Here, as in the pull force system, the two vertical forces form a vertical couple (outline arrows), which is balanced by the two horizontal forces of a horizontal couple (black arrows), *i. e.*, same moments in kg cm. In contrast to the pull system, the line of action of the effective seat contact was to the rear of the line of action of the subject's mass, the lines of action of the horizontal forces were reversed and the sense of the moments of rotation produced by the couples were reversed.

On the right hand sketch of figure 8 circles represent the relative masses of individual body parts; arrows directed downward indicate the lines of action of these masses. The masses were calculated from measurements of bulk made on the subject, and their vectors were located at centers of gravity based on cadaver data. As explained earlier, data on segment mass provided a means of checking the accuracy of the

calculated locations of action lines of whole body centers of gravity. A calculation of the counterclockwise moment produced by the mass of the trunk about the center of gravity should be equal and opposite to the clockwise moment produced by the sum of the masses of all other body segments. These moments for the subject and mean push position

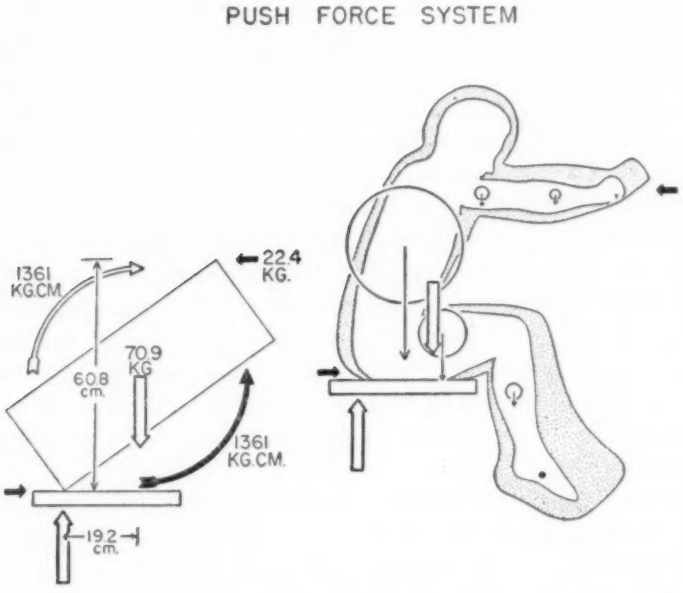

FIG. 8. At the right the stippled halo represents the range of body positions for 10 repetitions of one push posture; the most nearly average position is shown in solid black outline. The relative size of the masses of body parts is shown by the diameter of the circles and their lines of action by the vertical arrows.

illustrated were: $+342$ kg cm and -340 kg cm, respectively. Similar calculations for all selected positions were used as a check for the location of whole body centers of gravity.

Figure 9 is a block analogy of the push and pull force system, the heavy solid line in the left sketch shows a block tilted forward corresponding to a push position; at the right the block represents a pull position (tilted backwards). The horizontal forces recorded for a push or pull (black arrows) form the horizontal sides of a rectangle and the distances between these forces, the moment arms of the couple, form the vertical sides of the rectangle. Hence the area of rectangle A, the stippled area,

is a visual expression of the moment of rotation produced by the horizontal couple. Similarly, area *B*, crosshatched, represents the moment of rotation produced by the vertical couple. Area *A* is equal to area *B* in a balanced system. Thus the moment of the horizontal couple has the same magnitude as the vertical couple but the sense of its rotation is opposite. If the block tilts farther forward moving the center of gravity forward, or tilts backward, the distance between the two vertical (constant) forces increases, and area *B* becomes greater. If the force

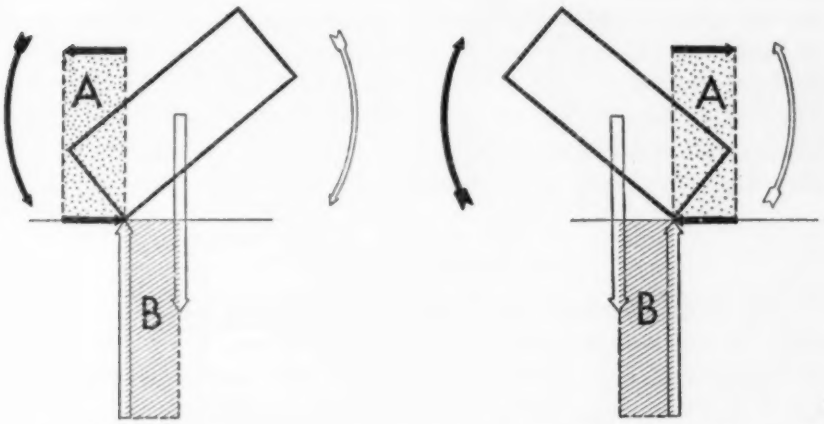

FIG. 9. In these figures a wooden block is substituted for the subject. The vertical and horizontal force couples with their moments of rotation are shown in the push system at the left and the pull system at the right. The moments of rotation are shown as rectangular areas (A and B); their magnitudes in a balanced system are equal and their directions of rotation are opposite.

system remains in equilibrium, there must be an equal increase in area *A*. Since the moment arm decreased with increasing tilt the horizontal force must increase notably for the equilibrium situation.

Under the conditions of the experiments the distance between the line of pull (or push) at the hand grip and the line of opposing force recorded by the compression gauge at the seat was fixed, *i. e.*, the subject could not alter the moment arm of the horizontal couple. Neither could he change the magnitude of his body mass; hence, the size of the vertical counterforce was fixed also. The only changes possible for the subject in order to increase hand force, were a lengthening of the horizontal moment arm through: (1) a change in the position of his whole body center of

gravity and (2) an adjustment of the point of effective seat contact. A simple tilting of the block moves the center of gravity relative to its lower contact corner. The subject, however, has a broad area of buttock (and foot) contact with the seat. The force per unit area (*i. e.*, stress) can concentrate at different parts of the area of contact; normally for the simple rest position the stress will be highest at the ischial tuberosities. Through muscular effort and by virtue of a contact with the hand grip the subject may bend certain joints and extend others and in this way he may concentrate the point of application of force at the seat either forward of the center of gravity (toward the hand grip) or behind it (farther from the hand grip). He thus lengthens the moment arm between the line of action of the body center of gravity and that of the effective seat contact. These changes in body tension which result in different points of force application can often be effected with very little change in the location of the whole body center of gravity.

THE MUSCLE CONTRIBUTION

Figure 10 illustrates muscle tensions which were observed by palpation. In pushing there was a general tension of arm, chest, and anterior abdominal wall musculature. Tension was felt also in the hip flexors and knee extensors. Extension of the legs and moving the center of gravity forward tended to increase both the clockwise rotation and the magnitude of the push force; thigh flexion which decreased thigh contact with the front of the seat moved the effective seat contact to the rear (*i. e.*, to the ischial tuberosities). In pulling, tension was felt in the arm, shoulder, and deep back musculature. Activity was noticed in the hip extensors and knee flexors. The former moved the effective seat contact forward, off the ischia, to the thigh contact with the seat; the latter action tended to prevent pulling the body off the seat by moving the center of gravity to the rear. In both positions these movements of body parts effected by muscle actions increased the moment arm of the vertical couple.

MOMENTS AND FORCES

On the basis of this analysis of the mechanics of our system, the subject should obtain the largest pull or push values when the moment arm of the vertical couple is greatest and the smallest pull or push values when the moment arm is least. Figure 11 illustrates the pull

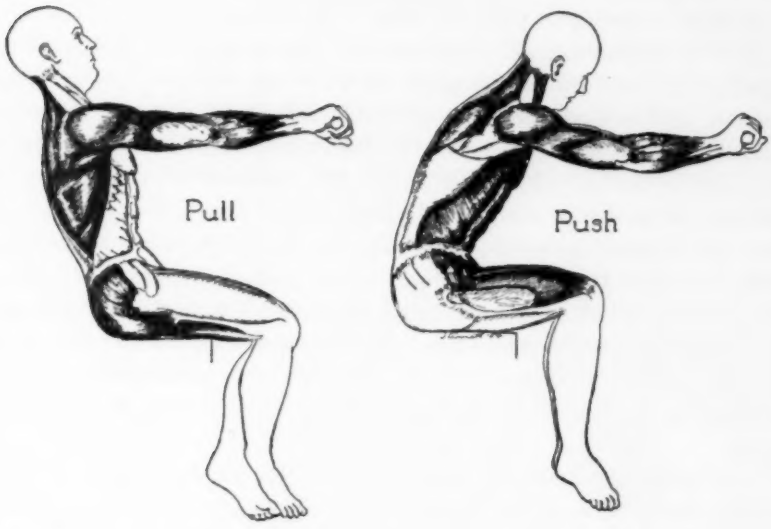

FIG. 10. Muscle tensions observed by palpation when the subjects effected horizontal pull and push forces.

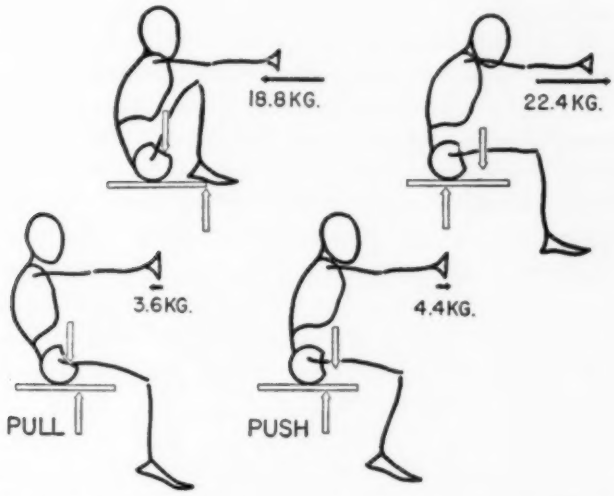

FIG. 11. Stick figures showing the push and pull positions in which a subject effected the indicated maximum and minimum horizontal force values.

and push postures in which the subjects obtained maximum and minimum force values (*cf.* table 1). In pull posture "a" (lower left) in which the subject leaned back passively grasping the hand grip and in push position "a" (lower right) in which the subject leaned forward passively on the hand grip, the moment arm of the vertical forces was minimal; notice that the horizontal forces were correspondingly small. In pull position "f" (upper left) and push position "f" (upper right), however, there was a considerable distance between the vertical forces (*i. e.*, the moment arm was maximal) and there was a correspondingly greater value of the horizontal force. The mean values for the moment arms of the vertical couple are listed in column 4 of table 1; the magnitude of the horizontal forces are listed in column 5. Columns 4 and 5 of table 1 show an increase in the size of the horizontal forces corresponding to an increase in the length of the moment arm of the vertical couple.

The hand dynamometer was set at a convenient height at about shoulder level for subjects A and B; the same height was used for each subject although A was somewhat shorter in trunk height than B. Subject C was tallest in trunk height and he could use only one push and two pull positions at the same height as the other two men; consequently, the dynamometer height was set three inches higher for 5 pushes and 4 pulls.

When the moment arms of the vertical couple for a subject were plotted as ordinates against the related horizontal forces as abscissae, a straight line plot was produced in each instance (fig. 12). The slopes of the curves for either pushes or pulls indicated that subject A produced a greater horizontal force for a given horizontal moment arm than subject B. Line *C* of the graphs was drawn through points resulting from a higher dynamometer position than for the other two subjects; one push value and two pull values (squares) fell well to the right of the line—these represented the lower dynamometer position mentioned above. If only values for the same dynamometer hight are considered, subject C produced more force that A who, in turn, produced more than B for a given moment arm.

All the moment-force data on the three subjects thus were mathematically consistent and confirmed the principle that the magnitude of horizontal force is proportional to the moment arm of the vertical couple for a given body weight irrespective of the body posture or the type of muscular action put into the effort.

GENERAL PRINCIPLES

The force system that has been analyzed truly consists of a closed chain (fig. 2) with an organic and inorganic component. The former consists fundamentally of the body links between the seat and the hand grip (*i. e.*, pelvic region and trunk, shoulders and the parts of the free limbs) and the other formed by the frame which supports the seat and

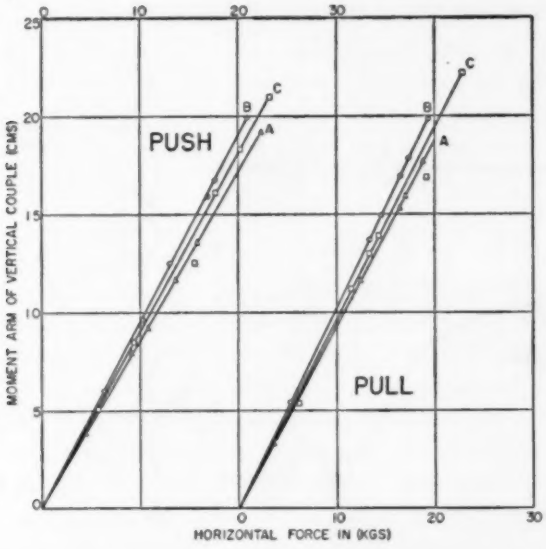

FIG. 12. The average magnitude of horizontal forces effected by three subjects (subject A, triangles; B, circles; C, squares) plotted against the respective average moment arms of the vertical couple for 10 repetitions of 6 different push and 6 pull positions.

hand grip (*i. e.*, hand grip, dynamometer, dynamometer support bar, the right hand uprights to the mid-level horizontal, the horizontal support and the seat with its fore-and-aft contacts with the frame). A detailed consideration of the vertical and horizontal force system operating in the support and framework is uncalled for here; it should be appreciated that any pull or push forces are opposed by stresses within the material of the framework. It is only through the action of counterforces (measured by the several dynamometers) that the body can express forces on its environment. In the rotational system considered, muscular tensions simply concentrate the stresses to the pelvis

or to the femora and thighs in different patterns. The contact with the hand grip as well as with the seat is a necessary condition for the development of the couples which have been treated above.

USE OF FOOT REST

The same principles apply when a foot rest is utilized. The sketch at the left of figure 13 illustrates the force system involved in the use of a seat plus a foot rest in horizontal midsagittal pulls. In the position

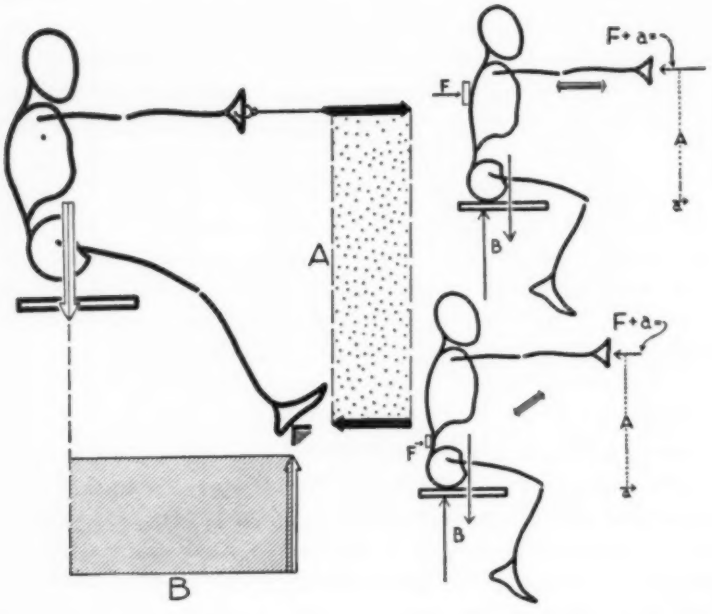

FIG. 13. At the left is a stick figure diagram illustrating the force vectors present when the subject utilizes a foot rest in producing hand pulls; at the right are two sketches showing the force vectors present in a push system utilizing a back rest at two different heights.

shown the subject pulled his maximum, transferring the point of effective contact from the front edge of the seat to the foot rest. The magnitude of the pull force for a test subject in this situation was 47.7 kg (horizontal black arrows in figure), the moment arm of the couple formed by the horizontal forces was 100 cm, and the moment of rotation produced by this couple (stippled area) was 4770 kg cm. The

subject's weight was 68.2 kg and was opposed by a reaction force of the same magnitude at the foot rest (vertical arrows). The moment arm of this vertical couple was 70 cm and the resultant torque was 4774 kg cm. The moments produced by the two couples (areas *A* and *B*) were, within the accuracy of measurements, in equilibrium.

The mechanics of this system is identical to that involved in the earlier tests utilizing seat alone. Here, however, the length of the moment arm of the vertical couple was increased by moving forward the effective body contact from the seat to the foot rest. It is to be noted also that the point of body contact was lowered. For a more effective use of dead weight, the foot rest should have been located closer to the horizontal level of the hand pull. It will be apparent from the diagram that push forces on a foot pedal will be maximal for the same conditions which bring forth maximal hand forces.

USE OF BACK REST

The back rest introduces a wholly new problem. In a series of tests, a back rest was placed at sacral, waist, xiphoid, and shoulder levels. Horizontal forces for one subject resulting from pushes at shoulder height were: 19 kg, 30 kg, 33 kg, and 40 kg, respectively. Two of these positions, waist and xiphoid, are shown by the sketches at the right of figure 13. Essentially the same torques due to body dead weight operated whether a back rest was utilized or not and the hand force would be proportional to the moment arm of the vertical couple, but an additional factor entered the force system when a back rest was used. The back rest supplied a stabilizing support against which upper limb and trunk muscles could operate to exert a direct horizontal pressure along the body links between hand grip and back rest. For the subject tested, the horizontal push force utilizing a back rest at waist height was increased by almost 20 kg over the value obtained by the use of dead weight alone; the value of the increment increased as the back rest was raised to shoulder height.

In the lower right sketch of figure 13 the couple involving the subject's dead weight produced a force "a" and the action of arm and trunk muscle tensions resulted in a direct horizontal pressure "F"; to produce force "F," the subject elevated his shoulders, arched his back, and tightened the extensor muscles of the arm to increase the compressive force acting obliquely across the arched strut between the back rest and the hand grip. The sum of the two horizontal components (F and a) represented the magnitude of the horizontal hand push.

If a shoulder harness were attached to a back rest, pull forces could be augmented in a reciprocal way. Now the pull force proportional to the horizontal moment arm of the vertical (weight) couple would be supplemented by muscle tensions operating along the chain: hand grip, arm and shoulder, harness and back rest.

OTHER APPLICATIONS

Although measurements were not extended to other situations it is apparent that the two principles outlined above (dead weight couples, and direct forces due to bracing) are not limited to the seated posture. A sidewise standing push or pull at shoulder height will be greater if the feet are planted far apart. If the near foot is lifted and the body weight is centered well ahead of the implanted foot, the push will be augmented. Conversely, if the rear leg is lifted and the near leg replanted firmly, the body weight acts well behind the near foot and a pull force will be high. Again, a lower height of push or pull will produce greater hand forces till foot friction with the ground forms a limiting factor. The addition of a tension or compression brace, *i. e.*, an inorganic linkage from hand to trunk, will permit the additional action of muscular forces across the upper limb links. For the seated operator a compressive brace at (or above) hip joint level will permit high foot pedal forces; if the trunk leans backward to produce a vertical force couple the back rest will need to be at perhaps lumbar level (Weddell and Darcus, '47; Rees and Graham, '52) for highest force values.

Further study of asymmetrical one-handed or one-footed static actions should bring out additional information concerning bracing and the action of couples in planes other than the sagittal; dynamic problems also warrant attention.

SUMMARY

This study was an investigation of a static force system of the closed chain type between test subjects and a rigid framework; the animate and inanimate components were linked at both the hand and seat contacts. A nude subject, symmetrically placed on a seat without foot or back rest, exerted a steady two-handed pull or push at shoulder level in the mid-sagittal plane. Suitable instrumentation provided a means of recording: (1) the subject's posture at the moment of a maximum force, (2) the distribution of vertical forces at the front and rear of the seat, and (3) the maximum horizontal reaction forces at the hand grip and at the seat. Three subjects were used and 10 repetitions were made of all

measurements in each of 6 stereotyped push and 6 stereotyped pull postures. Since pushes and pulls are possible only in a closed system, either couples acting in opposite sense or directly opposing forces can be involved. Two force couples, resulting in equal moments of rotation but acting in opposite directions, were recognized in the system. One couple, involving forces due to body weight, was composed of a downward force vector acting at the body center of gravity and an upward counterforce localized at the effective seat contact. The other couple involved the horizontal force exerted on the hand grip and the horizontal counterforce at the seat. The data from the study show that the subject, by muscle tensions, during hand pulls or pushes can change the location of the focus of a seat contact anywhere between the ischia and the lower thigh and thus alter the moment arm of the vertical force couple; the magnitude of the horizontal force is directly proportional to the moment arms of the body weight couple.

The introduction of a foot rest changed the point of seat contact from the seat to the foot rest, increasing the moment arm of the vertical couple and causing a greater resultant horizontal force. This modification, however, did not alter the basic mechanics involved. The use of a back rest, in contrast, provided a means by which the subject could exert a direct compressive force by tensing muscles against the resisting contacts to augment force values obtained by dead weight alone.

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BOOK REVIEWS

The Human Animal. By WESTON LABARRE. University of Chicago Press, 1954. Pp. xv + 372. $6.00.

In this attempt to formulate a unified anthropological view of man, the two main categories of interpretation are man's biological evolution and the orthodox psychoanalytic theory of human behavior.

As an anthropologist, LaBarre is interested in culture, interpreted as a function of biological evolution. In fact, he is so insistent on the biology of culture and human behavior that he refers to man time and again as "the human animal." In depicting man's organic evolution he makes extensive comparisons with other species, and particularly with the apes. One wonders whether apes today more closely resemble the behavior of some common ancestor than we do?

All mankind is one species, says LaBarre, with the important differences between "races" being functional or cultural, rather than biological. Culture is "man's ecology." It has freed man from biological evolution; continued evolution for him is cultural. ". . . the emancipated hand has emancipated man from any other organic evolution whatsoever. With man, genetic evolution and organic experiments have come to an end" (p. 89). An important aspect of cultural evolution is its "fantastic speed" when compared to biological; in addition, man has to pay no genetic price in physical specialization for his cultural evolution.

Chapters 10 and 11 are concerned with the analysis of communication, and the change from phatic to symbolic. The former gives "information about an individual animal's state of mind" (p. 57), and commits LaBarre to anthropomorphism (pp. 8, 18, 57, 165, 334); the latter refers to language. The development of language is related to biological evolution: language could have been developed only by an animal with man's organic evolution. LaBarre demonstrates quite effectively that our conception of reality is determined for us by the structure and concepts of our language. Thus language, which is the means to knowledge, is also effective in forever concealing from us the picture of reality as we would find it were we free of language. The effect of this cogent argument is later dissipated, however, when LaBarre tries to show that language is basically emotional rather than cognitive.

Cultural behavior, which is distinctly and singularly human, is interpreted by LaBarre in terms of orthodox psychoanalytic theory.

Everything centers around the oedipal situation and the permanent breast. Relations between the sexes, and differences in behavior between the sexes are biological-psychoanalytic: for example, generalization is male, but "biologically, women are closer to realistic particulars" (p. 212). It is "small wonder" that women in general are more "psychological-minded than men . . . They have to be, biologically." (p. 215). LaBarre's hatred of the father and adoration of the mother is not based on empirical investigation but on faithful acceptance of the word of his own god, namely Freud. One wonders to what extent this biological-psychoanalytic theory is or can be useful in relation to further study. For example, in what way will the study of human culture be advanced by applying individualistic concepts to collective phenomena? This is what LaBarre does when he concludes that the wisdom of a culture "is often enough mere senile dementia." (p. 365). Psychoanalysts may agree with LaBarre's unrestrained application of psychoanalytic interpretations to cultural evolution, but hardly any other group will.

The last chapter, "Three Minutes to Midnight," is concerned with the current scene. Militarism and political absolutism are conceived as imminent threats to continued cultural evolution; human speciation is now and has for long been cultural rather than organic.

Whatever one may think of specific details of *The Human Animal*, it should be said in its favor that LaBarre's position is openly stated throughout, even though it may be controversial. A good example is his conclusion that the hypothesis of the soul is a garment ill fitting modern man: it is poor physics, bad embryology, bad biology, poor psychology, and "a wholly inadequate anthropology." (p. 302).

The Human Animal, because the theme of the biological evolution of behavior runs through it from beginning to end, will probably appeal forcefully to those whose intellectual orientation is to biology.

Wayne University
Detroit, Michigan

FRANK E. HARTUNG

Teamwork in Research. Edited by GEORGE P. BUSH and LOWELL H. HATTERY. 191 pp. The American University Press, Washington, D. C., 1953. $4.00.

Interpretations of the term "human biology" vary. One definition, supported by the existence of monographs so labelled, is "an interdisci-

plinary study of man as a biological organism."* With behavior forming a link between the natural and social sciences, the boundary must remain open.

In any interdisciplinary area, team research represents the dominant mode of operation. For this very reason the present volume is of definite interest, even though the specific problems of team research in human biology are not considered in detail, and the case studies cited draw on applied physics, operations research, and the science of computation.

The volume is an outgrowth of the third Institute on the Administration of Scientific Research and Development, sponsored by the American University, the National Research Council, and the American Association for the Advancement of Science. It is a sequel to *Scientific Research: Its Administration and Organization* (American University Press, 1950).

The trend toward team research was accelerated by war-time projects. Some of these demanded a pooling of skills and knowledge which could only be provided by individuals with different scientific and technical specialization. The effectiveness of cooperative efforts in handling complex problems was amply demonstrated by such dramatic advancements as the development of the proximity fuse. At the same time, this *modus operandi* poses numerous problems not encountered by individual specialists working alone or with a few assistants on problems of limited scope.

The present volume is concerned with several aspects of team research. In addition to the case studies, noted above, it consists of 12 papers grouped under the headings of Organization for team work, Personnel factors, and Aids to teamwork. There is an introductory and concluding chapter by each of the two editors.

Research workers who are not expressly interested in administrative matters will still find the reading rewarding. Perhaps the "sideline" comments will be found most instructive. Do you not agree that *all* research is a type of production and as such must be planned, budgeted and scheduled (p. 25); that universities have been in the past and will continue to be the prime movers in the field of basic research (p. 39); that, in contrast, governmental agencies are likely to stress practical results and are not too anxious to wait around for a more basic understanding of a subject (p. 65); that the optimal size of a team is between

* A. Keys, J. Brožek, A. Henschel, O. Mickelsen and H. L. Taylor, 1950, The Biology of Human Starvation, University of Minnesota Press.

4 and 10 (p. 66); that adequate communication is a key factor in maintaining an effective team (p. 74); that there is an optimum in the pressure exerted to get a job done and that the creative activity within the group goes down if the pressure is substantially increased or decreased (p. 77); that the primary goal of any research administration is to maintain environment conducive to good research (p. 105); that an important facet of the research director's job is to clarify and to keep clear the ultimate aim of the investigations, inviting every member of the team to participate to the limit of his capacities in reaching out towards the common goal (p. 136); that unless the individual workers and the team as a whole are kept properly oriented and inspired, the chances are great that the product will soon sink to a level of mediocrity (p. 143); that the spirit of an institution transcends its formal organization and that the organization chart represents merely a framework, with the real dynamic power lying in the individuals who make up the organization and in their motivation to work together to achieve recognized objectives?

In summary, as disciplines fragment due to ever-increasing specialization and as problems increase in complexity, the need for a coordinated cross-disciplinary approach increases, is the normal state, and is mandatory (p. 186). This applies directly and definitely to all of the larger problems of human biology.

JOSEF BROŽEK

University of Minnesota
Minneapolis, Minn.

The Psychological Variables in Human Cancer: A symposium. Edited by JOSEPH A. GENGERELLI and FRANK J. KIRKNER. 135 pp. University of California Press, Berkeley, 1954. $3.00.

It is no longer novel to hear claims that psychological factors are significant in the etiology of the progress of physical disorders. It is novel, however, to find physicians and psychologists joining in an all-day symposium on psychological factors in neoplastic disorders. Let it be pointed out immediately that no one connected with the symposium claimed that thoughts or feelings can cause cancer. They did claim, however, that mental activity can influence the progress of the disease. Should the symposium be summarized in one sentence, it would go something like this: If a patient is serene he will do better with his

disease; if he is anxious, or otherwise agitated, his prognosis is poorer. According to the symposium, then, human cancer is a psychosomatic disorder, not in etiology, but in the course of the disease.

The symposium involved 6 reports with scheduled discussants for the first 5. M. Cutler "sang the theme song." It was he who claimed that, in his experience, patients who were "serene"—those who had faith in their God, their physician, themselves, or in any other factor—had a better chance for recovery.

Perhaps the most dramatic episode of the symposium was registered by the second participant, P. M. West. He described a patient who was explored for stomach carcinoma which was found to be nonresectable. Cancer cells were found in most of the stomach, the surrounding tissues, and even in the liver. The patient was discharged with the belief that his operation had been successful. Nine years later he was readmitted with a fatal heart disease. Autopsy showed *no* tumor cells. His wife said that "her husband had . . . had [no] stomach distress . . . and had been perfectly well until the day of the heart attack."

The remainder of Dr. West's report traced the history of his conclusion that psychological factors play a role in the course of cancer. He was the goad for the other reports of the symposium—in fact, the symposium itself.

F. W. Ellis, a colleague of Dr. West at the Veterans Administration Hospital at Long Beach, California, presented case summaries which tended to support the general theme of the symposium. Two reports represented doctoral dissertations by psychologists. E. U. Blumberg concluded that the Minnesota Multiphasic Personality Inventory and the Rorschach test, together, could separate patients with fast-growing and slow-growing cancer, and B. Klopfer, as a discussant, presented a convincing theoretical analysis of Blumberg's results.

T. L. Clemens sought to test the hypothesis that apparent hyperactivity of the sympathetic branch of the autonomic nervous system is prejudicial toward recovery from cancer. Specifically, he tested patients with slow and fast-growing cancer and found some significant differences in autonomic function. His results need verification, as do Blumberg's, but the conclusions of both are in harmony with the theme of the symposium. The concluding report, by the chief psychiatrist at the host hospital, J. S. L. Jacobs, was an erudite presentation of the concepts of host-resistance and host-acquiescence with an argument for the value of the latter in some psychosomatic disorders.

The reviewer believes that the symposium was ill-timed. It was held too soon. Neverthless, the observations deserve attention and the conclusions reported in this symposium may be regarded as essentially valid. Apparently, cancer is not *just* an "organic" disease and there are ways of alleviating its destructiveness involving other tools than those of the radiologist and the surgeon.

M. A. WENGER

University of California
Los Angeles, California

Social and Psychological Factors Affecting Fertility, Volume 4. Edited by P. K. WHELPTON and CLYDE V. KISER. vi + 801-1086 pp. Milbank Memorial Fund, New York, 1954. $1.00.

Culture and Human Fertility. Edited by FRANK LORIMER. 510 pp. Unesco, Paris, 1954. $4.50.

Induced Abortion on Psychiatric Grounds. By MARTIN EKBLAD. 238 pp. Ejnar Munksgaard, Copenhagen, 1955.

Sexuelle Konstitution. By HELENE STOURZH-ANDERLE. ix + 262 pp. Wilhelm Maudrich, Vienna-Bonn, 1955. $6.25.

The first of these volumes, number 4 in the series of the same title, contains 7 further studies. Swain and Kiser examine the interrelationship of fertility, fertility planning, and ego-centered interest in children. Schacter and Kiser inquire into the fear of pregnancy and childbirth. Westoff, Hererra and Whelpton discuss the use, effectiveness, and acceptability of methods of fertility control. Westoff and Kiser make an empirical re-examination and intercorrelation of selected factors—marital happiness, feeling of personal adequacy, tendency to plan in general, and feeling of economic security. Kantner and Kiser examine the interrelation between fertility, fertility planning, and intergenerational social mobility. Riemer and Kiser report on economic tension and social mobility in relation to fertility planning and size of planned family. Finally, Kantner and Potter report on the relationship of family size in two successive generations.

Culture and Human Fertility is a study of the relation of cultural conditions to fertility in non-industrial and transitional societies. To this field of population studies it represents a major contribution. Notestein in the preface gives a succinct amount of the origin of the volume,

and Lorimer contributes a most stimulating and valuable section on general theory which will be of equal interest to cultural anthropologists as to human biologists. In part two Professor Fortes reports the results of a valuable field study in Ashanti, West Africa. Fortes makes much new information available and brings valuable evidence to the support of the theory of adolescent sterility. In part three K. A. Busia discusses some aspects of the relation of social conditions to human fertility in the Gold Coast. Richards and Reining report on fertility surveys in Buganda and Buhaya in 1952, and indicate something of the difficulties of obtaining reliable demographic information among nonliterate peoples. In part five Mortara reports on the Brazilian birth rate and the economic and social factors. There is a good index.

Scandinavia shelters one of the most civilized populations in the world. In Sweden there has been a law which enables women, who for psychological or other reasons would suffer from an unwanted pregnancy and its issue, to undergo an abortion. In the present monograph Dr. Martin Ekblad reports on a follow-up study of 479 women in whom abortions were induced on psychiatric grounds. His study is as exhaustive as such a study can be, and his conclusions are that on the whole the abortions were personally and socially beneficial, and he recommends, on very good grounds, that where sterilization is indicated it should more frequently be induced.

The last volume is the first in a new series entitled Wiener Beiträge zur Sexualforschung under the editorship of Dr. W. F. Brix. *Sexuelle Konstitution* is a popularly written work of a type which one associates with Vienna, the Blue Danube, and "Gemütlichkeit." The book is about the constitutional basis of sex, not a scientific work, but the reflections of the author on sex with especial reference to constitution, psychopathy, criminality, and genius, in which the data of science are used as the author chooses with a preternatural reliance on secondary sources. Most of the important work done outside German-speaking countries is largely neglected by the author. The facts are often questionable, and the author's opinions are usually debatable. This does not, however, prevent them from being both interesting and interestingly expressed.

ASHLEY MONTAGU

Princeton, New Jersey

Man in a Cold Environment. By ALAN C. BURTON and OTTO G. EDHOLM. xiv + 273 pp. Edward Arnold, London, 1955. $6.75.

The relationship between man and his environment is becoming more complex as the inhabited areas are rapidly expanding toward the poles and to zones well above and below the surface of the earth. Cold is common to much of this extended domain and it is urgent to increase our understanding of the impact of cold on man. A unique presentation and interpretation of the status of our knowledge of this subject by two well qualified authors is not only welcome and valuable for purposes of orientation but should stimulate further interest and work in this important field.

Several features of the book are outstanding: a consistent scheme for describing heat exchange is followed throughout; overall organization and chapter organization is excellent; and the many topical summaries reinforce points the authors wish to stress. Treated in turn are philosophy, physical concepts of heat exchange, physiological maintenance of the thermal steady state, impact of the environment on animals and man, consequences of acute and prolonged heat imbalance, and future problems for research. Selected pertinent literature relevant to these topics is critically presented, analyzed and discussed. Several un-numbered tables, 75 figures and illustrations and numerous equations support the text. Since the cut-off date for published literature was December 1951, workers in the field will note instances where data from subsequent experiments have modified interpretations and conclusions (for example, the recent work of Rodahl has indicated that diet is largely responsible for the higher basal metabolism in Eskimos). This, fortunately, is an indication of progress and not a criticism of the monograph.

The original purpose of the monograph was to make available the wartime military reports on man in the cold. This aim was modified "as the physiological content of importance was found to be small" in many of these reports. This comment is no doubt true but perhaps many of these reports contain "buried" information, which, if subjected to consolidated statistical analysis, would provide valuable information. Since an analysis of this type was beyond the scope of the present contribution, a thorough review of the wartime work still remains to be accomplished.

R. E. BUSKIRK

Stress Physiology
QM R and D Command
Natick, Mass.

Cold Injury, Third Conference. Edited by M. I. FERRER. 226 pp. Josiah Macy, Jr. Foundation, New York, 1955.

The third conference on cold injury was held at Fort Churchill, Manitoba, Canada, during the month of February 1954. Thus, the panel of participants was unequivocally close to the topic of mutual interest and discussion. Various workers presented their findings on pertinent problems asociated with cold exposure, including interrelationship of circulatory and metabolic factors, metabolic study of the Eskimo, comparison between Eskimo, Indian, and White males, fat distribution and respiratory quotient, diet and survival, and the roles of ascorbic acid and subcutaneous fat in the prevention of cold injury in man. Spirited criticism and discussion of each presentation took place. Supplementary data provided by discussants is included in the text for the reader's benefit. In addition, the reader benefits from critical evaluations of the papers. Frequently, however, he is confused by the lack of continuity of discussion. Unfortunately, summaries of pertinent findings are not included. This seems to make the present book, and in general, most books of this type, incomplete.

E. R. BUSKIRK

Stress Physiology
QM R and D Command
Natick, Mass.

Genetics and Metabolism. By ROBERT P. WAGNER and HERSCHEL K. MITCHELL. xi + 444 pp. John Wiley, New York, 1955. $7.50.

The statment E. B. Wilson made in 1896 that ". . . inheritance is the recurrence, in successive generations, of like forms of metabolism" has lost none of its validity. The book by Wagner and Mitchell is a highly successful attempt to assemble the data which support this concept. It is quite clear that hereditary factors control patterns of metabolism, but the *mechanisms* through which the control is exerted are still very incompletely understood. This book is perhaps the first to point up the problems which must be solved before we become acquainted with the genetic mechanisms of metabolic control and therefore provides the extremely valuable stimulation which generally comes from pioneering endeavors.

The authors provide a lucid introduction to genetics and a descrip-

tion of cell structure and function in the first two chapters. These are essential for the non-geneticist if the rest of the book is to fulfill its purpose. Fortunately, the authors also teach a good bit of chemistry in the subsequent chapters, which will be as helpful to geneticists as to all other non-chemists.

Most of our knowledge of the genetic control of metabolic patterns comes from studies with a mold (Neurospora), bacteria, fruit flies and mice. It might seem that these tiny forms of life are too distant relatives to provide anything of value to an understanding of human biology. However, the fundamental relationships between gene and enzyme are probably very similar for all forms of life as the Mendelian laws of heredity function in the same ways in both men and molds. There is very little in this book which is *not* fundamental to an understanding of the physiology of man.

An excellent chapter on cytoplasmic inheritance should convince the reader that the authors were not lost in their genes. They have a clear conception of the relative functions of cytoplasm and nucleus, and progress in research on human metabolism will proceed fastest if the relationship between nucleus and cytoplasm is kept in mind.

This book is not recommended as lunch reading but as a course of work for the serious research worker anywhere in the field of human biology.

SHELDON C. REED

University of Minnesota
Minneapolis, Minn.

An Introduction to Human Biochemical Genetics. By H. HARRIS. iv + 96 pp. Cambridge University Press, London and New York, 1953. $2.75.

The study of human biochemical genetics was initiated at the beginning of this century almost simultaneously with the rediscovery of the Mendelian rules for heredity. An English physician, Sir A. E. Garrod, was responsible for much of the early interest in human biochemical genetics. In the last decade the subject has flourished and Dr. Harris' book brings together the main advances since Garrod.

Although our knowledge of chemical variation in man is still very much in its infancy and is confined to a rather haphazard series of examples, the facts that have been discovered are of prime importance to the train of thought of the "human biologist."

This monograph is not only concerned with traits which are obviously the result of metabolic errors but also with differences in taste sensitivity to the thioureas. Even this group of genetic differences in the reaction of people to biochemicals may have some significance for health and survival. It has been apparent for some time that even the classical blood groups of Landsteiner can no longer be thought of simply in terms of genetic symbols. The blood group genes influence the specificities of mucoid materials in all the organs and body fluids. These genes have survival values which are of considerable magnitude, even though the selective value varies with the remainder of the genotype and the environment of each person.

Dr. Harris has succeeded admirably in reviewing the literature on biochemical genetics. Even more important is his capacity for exciting interest about research of the future. All sorts of unexpected discoveries result from almost any thorough study of the genetics *and* biochemistry of practically any human trait. Many of the readers of *Human Biology* will find themselves playing a part in this research eventually if they are not already involved in one way or another.

SHELDON C. REED

University of Minnesota
Minneapolis, Minn.

BOOK NOTICES

SCIENTIFIC METHOD IN PSYCHOLOGY. By Clarence W. Brown and Edwin E. Ghiselli. ix + 368 pp. McGraw-Hill, New York, 1955. $6.00. Like Caesar's Gaul, the volume is divided into three parts, starting with general ideas about the scientific method (with the control of psychological variables, and some facts and principles of psychological measurement added for good measure), continuing with steps in the application of scientific method (defining the problem, collecting the facts, analyzing and interpreting the data), and ending with some special problems of methodology (the physical testing situation, variables associated with the responding subject, quantification of behavior under conditions of laboratory experimentation, and some problems of field studies). A useful addition to psychological textbook literature.

FUNDAMENTALS OF ECOLOGY. By Eugene P. Odum. xii + 384 pp. W. B. Saunders, Philadelphia, 1953. $6.50. The book was intended to serve two purposes: as a college textbook and as a reference for those engaged in a variety of fields in which ecological principles are applied, including public health and welfare. There is a brief chapter on the more direct applications to human society, with emphasis on the interaction between the "natural" and the "cultural" aspects of human ecology.

MOTIVATION AND PERSONALITY. By A. H. Maslow. xiv + 411 pp. Harper, New York, 1954. $4.50. Historically, psychiatry and not experimental psychology, the study of emotionally sick and not of the happy and well-adjusted individuals provided the basis of the "scientific" picture of human nature. The author rejects such a portrait and calls for *positive* psychology, studying healthy human beings at their full height. The appendix on "Problems generated by a positive approach to psychology" might usefully serve as required reading for candidates choosing the topic for their Ph. D. thesis. A thoughful, pioneering, provocative book.

THEORIES OF PERCEPTION AND THE CONCEPT OF STRUCTURE. By Floyd H. Allport. xxii + 709 pp. John Wiley, New York, 1955. $8.00. When a mature social psychologist embarks on a study of perception, a field heavy-laden with facts and theories, there are only two alternatives: the outcome will be either tripe or a significant, stimulating contribution. Happily, in this case, it is the latter. The objective of the labor was twofold: to survey and bring order into the modern psychological theories of perception, the process by which organisms obtain information about the world in which they live, and to outline the author's concept of structure, applied to human behavior and social action, and presented within the framework of a more general "theory of structuring of events." The implications for various fields of science, beyond the study of perception, are to be developed in a future volume or volumes.

TEXTBOOK OF BIOCHEMISTRY. 2nd edition. By Edward S. West and Wilbert R. Todd. xii + 1356 pp. The Macmillan Co., New York, 1955. $12.00. Within the span of a quarter century, biochemistry developed into a vastly complex science, with new techniques (such as the use of isotopic atoms to trace the chemical pathways of substances in the body) contributing to its accelerated rate of growth. The second edition continues the comprehensive coverage of the field, incorporating the principles of physical and organic chemistry. Implications of biochemistry, including nutrition, for medicine are considered. Expansion of the section on chemical body composition (p. 382) in the next edition may be useful. Similarly, the methods for the study of body composition *in vivo* seem to have earned the price of the admission ticket.

ADVANCES IN EXPERIMENTAL CARIES RESEARCH. Edited by Reidar F. Sognnaes. ix + 236 pp. American Association for the Advancement of Science, Washington, D. C., 1955. $6.75. The monograph presents results of researches on the experimental production and prevention of tooth decay in laboratory animals. In view of the complexity of the subject (reflected in the participation of investigators representing anatomy, pathology, zoology, biochemistry, nutrition, and bacteriology as well as dentistry), the résumé on the effect of various agents tested in reference to experimental animal dental caries (with doubts cast on the adequacy of acidogenic theory of dental decay) and the editor's general summary will be found useful.

KINSHIPS OF ANIMALS AND MAN: A textbook of animal biology. By Ann H. Morgan. viii + 839 pp. McGraw-Hill, New York, 1955. $6.75. A good undergraduate textbook of animal biology. While man is also considered, the material is predominantly zoological.

AN INTRODUCTION TO HUMAN ANATOMY. By Clyde Marshall and Edgar L. Lazier. xiii + 420 pp. W. B. Saunders, Philadelphia, 1955. $4.50. The fourth edition of an elementary text.

EXPERIMENTAL DESIGN AND ITS STATISTICAL BASIS. By D. J. Finney. xi + 169 pp. The University of Chicago Press, Chicago, 1955. $4.50. An outline of the theory and practice of experimental design aiming to be intelligible to students and research workers in most fields of biology. It is not a textbook and not a cook book. Its principal purpose is to arouse the reader's "interest in a subject whose importance to good research practice is increasingly recognized."

INDUSTRIAL SOCIETY: The Emergence of the Human Problems of Automation. By Georges Friedmann. 436 pp. The Free Press, Glencoe, Ill., 1955. $6.00. The subject matter is much the same as one finds in textbooks of industrial psychology. However, the presentation is fresh, smooth, and stimulating. Some of the European experiences in the field of industrial relations will be of special interest to the American reader. Rightly, the interdependence of the technological, physiological, psychological and sociological facets of industry is stressed. "In this rich field, the coexistence of different per-

spectives and levels has been recognized; each of them contains an aspect of reality and none of them reveals the whole of it." Industrial mechanization is reviewed as a great experiment in the history of civilization.

FROM CUSTODIAL TO THERAPEUTIC PATIENT CARE IN MENTAL HOSPITALS. By Milton Greenblatt, Richard H. York, and Esther L. Brown. vii + 497 pp. Russell Sage Foundation, New York, 1955. $5.00. The evaluation of new concepts and more humane and effective practices in the care and treatment of the mentally ill is presented in reference to three outstanding hospitals. What has been learned through study of the hospital social system and analysis of ward care and through direct experiment has wide application, both to the institutional treatment of mental disorders and the broader problems of mental health and disease.

LAS TREPANACIONES CRANEANAS EN EL PERÚ EN LA ÉPOCA PRE-HISPÁNICA. By Francisco Graña, Esteban D. Rocca, and Luis Graña R. 340 pp. Imprenta Santa Maria, Lima, 1954. (no price). While therapeutic neurosurgery is one of the most recent additions to scientific medicine, cranial trepanation is a surgical procedure with longest firmly established history. The authors examine in detail the development of cranial surgery in the territory of Peru during the long years from 3,000 B. C. to the 16th Century of our era. A review of earlier studies (1865-1951), description of the material, operative technique and instrumentation, ideas about the etiopathogenesis, and comment are presented in turn. Numerous illustrations.

THE HARVARD LIST OF BOOKS IN PSYCHOLOGY. Compiled and annotated by the psychologists in Harvard University. viii + 84 pp. Harvard University Press, Cambridge, 1955. (no price). 607 books are listed, with a brief evaluative comment, in 30 categories. A useful bibliography of contemporary psychology.

THE HUMAN MACHINE: Biological Science for the Armed Services. By Charles W. Shilling. xii + 292 pp. U. S. Naval Institute, Annapolis, 1955. $5.00. Originally designed for the Hygiene Department of the U. S. Naval Academy as the basis for instruction in biological science. Part One deals with the construction and operation of the human machine, Part Two, with problems of maintenance (including personal, community, military hygiene), Part Three, with man as a part of the war machine (including submarine and aviation medicine, and atomic, biological, and chemical warfare). A non-technical, readable presentation.

JOSEF BROŽEK

University of Minnesota
Minneapolis, Minnesota

INFORMATION FOR [illegible]

HUMAN BIOLOGY, a record of research in [illegible] devoted to the subject its name implies. [illegible] articles dealing with human genetics, [illegible] duction and aging, functional anatomy, bio[illegible] ecology, population dynamics, etc.

The original manuscripts, typed double-[illegible] 8½ x 11 inch paper in complete and finished form [illegible] are to appear, should be sent—packed flat—[illegible] Gabriel Lasker, Wayne University College [illegible] Rivard Street, Detroit 7, Michigan. It is desired that a second copy be included in order to expedite prompt consideration. [illegible] that an additional carbon copy and copies of all illustrations should be retained by the author.

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Authors will receive 25 free reprints. Orders for additional reprints should be placed at the time proof is returned. It will not be possible to accept orders for reprints after the proof has been returned to the press.

Human Biology

a record of research

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